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EXAMPLE IS BETTER THAN PRECEPT

Waterbury and Bull's Bridge Plants

By Warren O. Rogers

SYNOPSIS—The Waterbury plant consists of four steam turbine units and a large transformer station. The latter converts the electrical energy generated at the Bull's Bridge hydro-electric plant and the steam turbines to voltage suitable for commerical use. The Bull's Bridge plant contains six 1000-kw. hydro-electric turbo-generators.

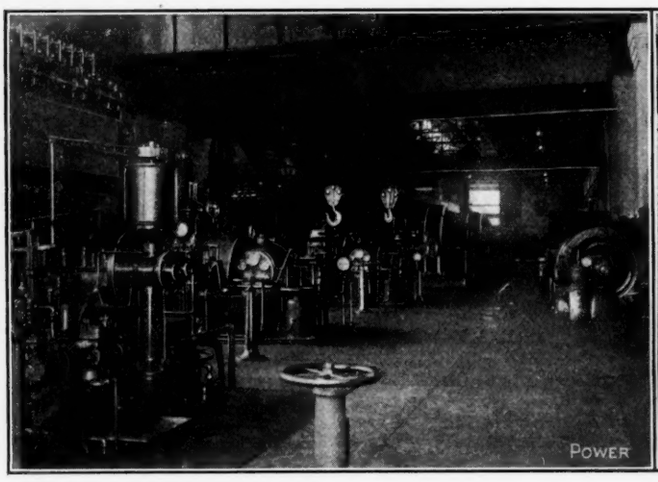

Fig. 1. Turbo-generator Room from the Turbine End

Fig. 2. Generator Room from the Transformer End

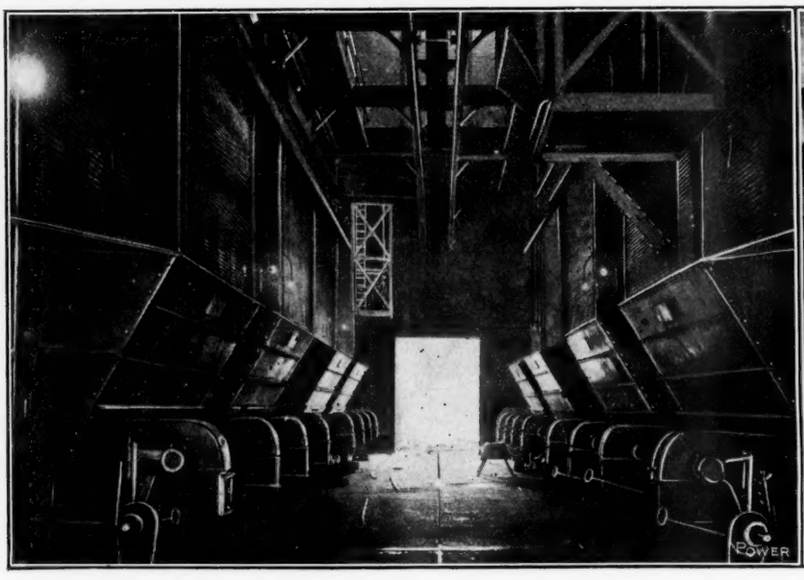

Fig. 3. Eight 500-hp. Water-tube Boilers

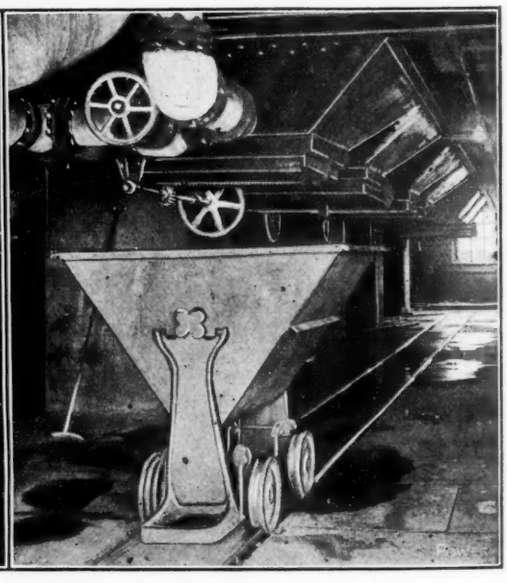

Fig. 4. Ash Car in Boiler-room Basement

What is now known as the Waterbury turbine plant of the Housatonic Power Co., Waterbury, Conn., was originally a substation, used for transforming the electrical energy generated at the hydro-electro station of the company located at Bull's Bridge, Conn., to commercial voltages.

The older part of the building is still used to house transformers of various types, and rotary converters for railway load, but the new extension in which the turbine-driven generators are installed forms a continuation of the transformer room. This enables the operators to have an unrestricted view of the entire electrical equipment.

Turbines and Condensers

In many respects the steam-generating plant is a duplicate of the power plant recently built at Zylonite, Mass., and described in Power, July 4, 1911. There are three steam turbines, placed crosswise of the generator room, Fig. 1. The largest is of 3000 kw., running at 1800 r.p.m. The other two turbines are of 1500 kv.-a. capacity, running at 3600 r.p.m. All use steam at 175 lb. pressure, superheated 75 deg. F. Each turbine exhausts into a jet condenser. The larger unit is supplied with condensing water by a turbine-driven, 20-in. volute pump and each small turbine condenser by a turbine-driven, 12-in. volute pump. The speeds are 970 and 1750 r.p.m.

and the turbines are of 125 and 25 hp., respectively, at 175 lb. steam pressure. The large condenser is piped to a 12 and 22 by 18-in. steam-driven dry-air pump; the other two condensers are each connected to an 18 and 20 by 12-in. steam driven dry-air pump. Work is also under way in installing another steam turbine of 4000 kw. capacity.

These auxiliary units are in the basement between the concrete columns forming the supports for the turbines. Steam superheated 75 deg., at boiler pressure, is used on all auxiliaries.

All condensing water is taken from the Naugatuck River, which flows past the plant.

Directly coupled to the large turbine is a 3000-kw., alternating-current, three-phase, 60-cycle, 2300-volt generator. The small turbine generators are of 1500 kv.-a. capacity; the voltage is 2300 and the amperage 373 per terminal.

Exciter Units

There are two 125-volt turbine-driven exciter sets, each of 100 kw. capacity at a speed of 1800 r.p.m. These units are placed lengthwise at one side of the room, Fig. 1, and at the head end of the turbines. There are no motor-driven exciter units, as the exhaust steam from the auxiliary turbine can be used to advantage in heating the feed water.

Boiler Room

The eight 500-hp. water-tube boilers are in a room built on the back of the extension to the old transformer station, and are in four batteries of two boilers each, as shown in Fig. 3, with a firing alley between the two rows. The furnaces have mechanical stokers operated by chain drive from a shaft running under the stokers in the basement. This shaft is belt-driven from the blower turbine, also in the basement. The boilers are all equipped with superheaters.

Draft Control

For the draft there are two forced-draft fans, each driven by a 150-hp. turbine. These are in the basement and the air is delivered to a sheet steel air duct running beneath the boiler furnaces. Four outlets extend from the top, each dividing into a Y, making eight branch pipes, which are extended to the ashpit of the eight furnaces. The speed of the turbines driving the forced-draft fans is controlled by a steam damper regulator. The uptake damper is controlled by a regulator actuated by the air pressure in the furnace.

In a room above and at one end of the boiler room are four 12-ft. fans, each driven at constant speed by a side-crank, slow-speed, piston-valve engine. The flue gases from each set of four boilers pass through an economizer back of each set of boilers. After passing through the induced-draft fans the gases are discharged through two

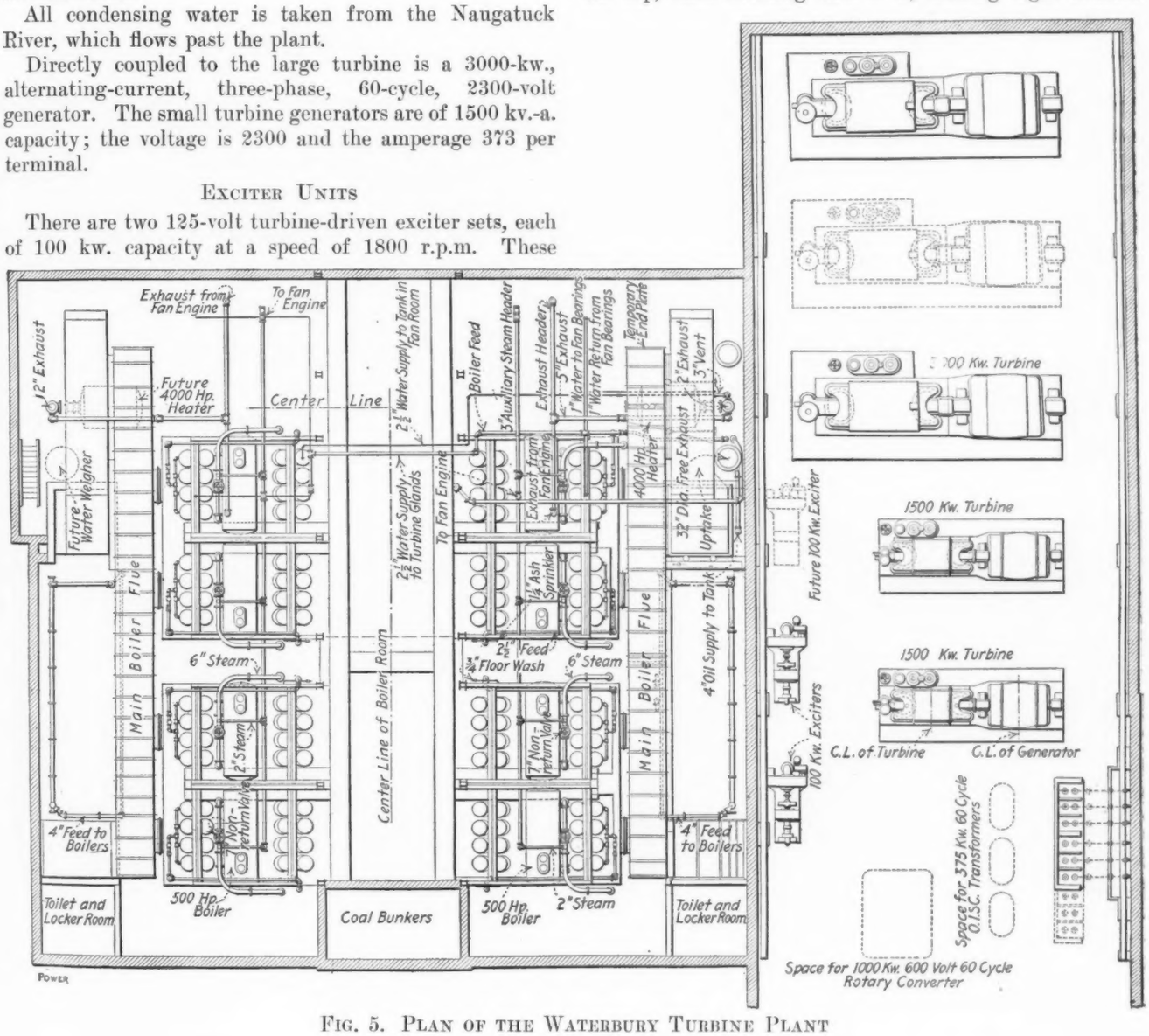

Fig. 5. Plan of the Waterbury Turbine Plant

10-ft. stacks. A 3-in. draft is created by the forced-draft fans, but the induced draft is much less, varying from 0.3 to 0.5 in. A third forced-draft fan is also installed, driven by a 600-volt direct-current motor of 50 to 100 hp. capacity, running at 80 to 960 r.p.m.

Feed Water

Water for boiler feed is pumped from the Naugatuck River by a 14 and 12 by 12-in. duplex pump in the turbine-room basement. The feed water is pumped through an open feed-water heater, and a water weigher to two iron hotwell tanks in the basement from which it is pumped through the economizer to the boilers by either of four

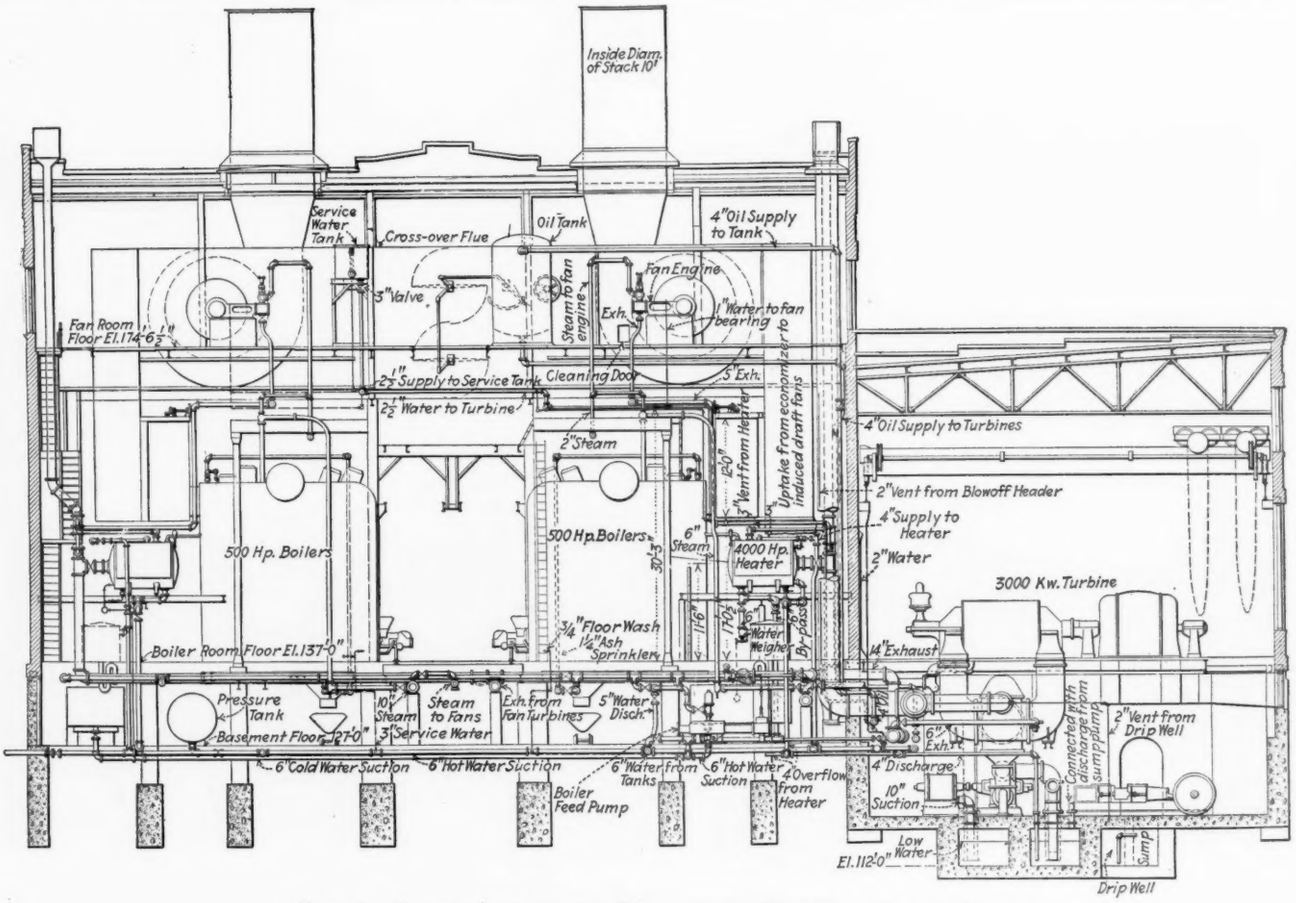

Fig. 6. Section through Waterbury Turbine Power Plant

12 and 7 by 18-in. outside-packed duplex, pot-valve pumps.

Coal and Ash

Coal is delivered to the boiler-room coal-storage bin by a scraper conveyor from a hopper below the ground surface in the yard. The fuel is dumped through the bottom of hopper cars into the conveyor hopper and is carried to the 75-ton coal service bunker at a rate of 40 tons per hour, passing through a set of crushing rolls. Fuel is transferred from the service bunker to the stokers by two electrically operated traveling weigh hoppers, each of 5-ton capacity. Each weigh hopper has a spout through which the coal is delivered to the stoker hoppers, and scales for weighing the coal.

Ashes from the stokers drop into ashpit hoppers having slanting sides and sliding bottom plates which are opened or closed by a rack and pinion operated by a hand-wheel, shown in Fig. 4. When the ash hoppers are to be emptied, an ash car is run under the gate and after loading is run out and dumped in the yard, which is on a level with the basement floor. The space beneath the conveyor is used for storing coal, which when wanted is shoveled into a small coal car and run to the conveyor hopper on a track. A monorail coal handling system, for reclaiming coal from the storage pile, is now being installed.

The old section of the present building is used as a substation, containing the necessary step-down transformers and rotaries, for supplying the railway circuits, and the necessary step-down transformers for reducing the transmission line voltage from 33,000 to 2300 volts for distribution to the various lighting and power lines.

The railway equipment consists of two 1000-kw., 600-volt direct-current, six-phase, 60-cycle rotaries and two 500-kw., 600-volt, direct-current, six-phase, 60-cycle rotaries, with the necessary transformers for stepping down from 33,000 volts to 440 volts; one motor-driven boosting generator for boosting the voltage on the long outlying lines.

There are two banks of oil-cooled transformers, each consisting of three 600-kw., single-phase transformers delta connected, for reducing the voltage from 33,000 to 2300 volts for distribution to the various lighting and power lines. There are seven constant-current transformers for supply to alternator-current arc circuits. These are complete with necessary individual plug switchboards, as shown in Fig. 2. Each transformer is of the air-cooled type and 500 kw. capacity. The cooling air for air-cooled

equipment is supplied by two motor-driven fan blowers, the normal air pressure being 5/8 oz.

Part of the oil switches are motor operated and part solenoid operated, the more modern type being the latter. The 33,000-volt switches are located on the main floor between the wall and the transformers. The 2300-volt switches are located in the bus structure in the basement directly under the switchboard. This switchboard consists of a 50-slate panel and is placed along the opposite side of the transformer room from the oil switches before mentioned. Fifteen of these panels are for lighting and power circuits; 12 are for the rotary converters, booster and instrument panels; 13 are 600 volt, direct-current railway feeder panels; six are 33,000 volt high-tension

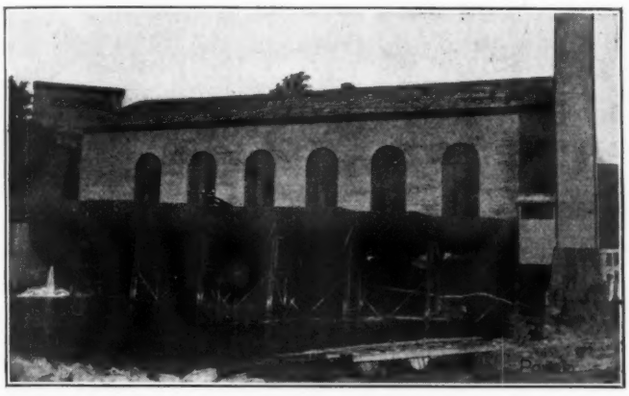

FIG. 7. HYDRO-ELECTRIC POWER PLANT, BULL'S BRIDGE, CONN.

panels and four are 2300-volt, three-phase generator panels.

The building is of red brick. The boiler room adjoins the new section, the building as a whole being L-shaped. There are two hand-operated cranes, one above the transformer section, and one over the turbines. The first is of 10 tons and the other of 35 tons capacity. A plan and elevation of the turbine plant is shown in Figs. 5 and 6.

HYDRO-ELECTRIC POWER PLANT

Thirty-two miles from Waterbury is the Bull's Bridge, Conn., hydro-electric power plant of the Housatonic Power Co., which is run in connection with the Waterbury steam station. The building is of concrete and has a wing containing the switchboard and transformers. Fig. 7 shows a rear view of the building and penstock. The Housatonic River is dammed at Kent, two miles above the power plant.

The water is taken from above the dam, two miles above the forebay, which is just above the gate-house on the hill, shown in Fig. 7. Here the water is controlled by gates and delivered to the water turbines through a 13-ft. penstock, which is reduced in size at each intake to a waterwheel. The penstock rests upon concrete supporting blocks from the gatehouse to the end of the power house, and upon supporting forms made of I-beams and saddles at the rear of the station, as shown. Water to each of the 2000-hp. hydraulic turbines is controlled by a hydraulic gate valve; a three-way valve in a bypass pipe connects with the top and bottom of the valve cylinder controlling the admission of water to the valve plunger. The three-way cock is operated by hand chains by the operator while standing on the floor.

Each of the six turbines is directly coupled to a 1000-kw. alternating-current generator running at 400 r.p.m. The voltage of each machine is 1150. A general view of the generator room is given in Fig. 8. The shaft of each generator extends out beyond the outboard bearing. This permits moving the bearing out on the base extension and also moving the generator casing sidewise so that the armature is accessible without getting the shafting out of alignment.

Belt-driven waterwheel governors regulate the speed of these turbines, each independent of the other, as shown in Fig. 9.

The two exciter sets are driven by water turbines, each directly coupled to a 125-volt, direct-current generator.

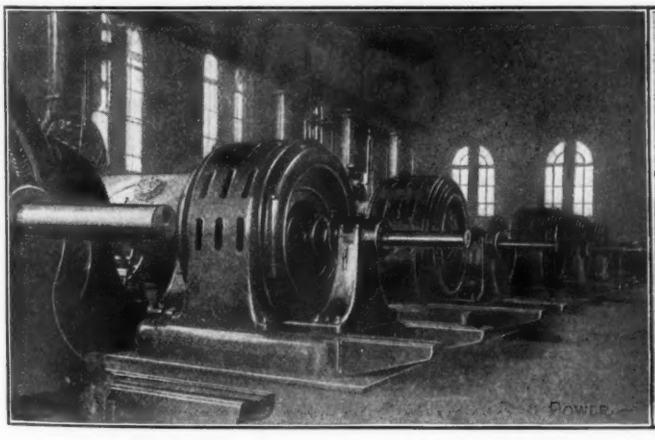

FIG. 8. HYDRO-ELECTRIC GENERATOR UNITS

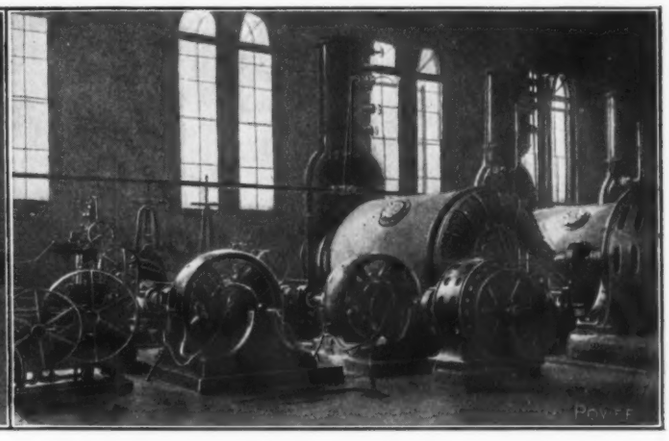

FIG. 9. EXCITER UNITS AND HYDRAULIC GOVERNOR

Connection is made with the main penstock by a 36-in. pipe having a Y-connection at the inner end and an 18-in. branch to each water turbine. One of the exciter units is directly coupled to a 100-hp. induction motor, which is used to operate the exciter generator after the main units have been brought up to speed and phased in. Each exciter unit is governed by a belt-driven hydraulic governor. This is all of the machinery in the hydro-electric plant.

A view of the marble switchboard is shown in Fig. 10. It is on a balcony facing the generator room. Underneath are the motor-operated oil-break switches. In a room back of the switchboard are the seven 850-kw. transformers, Fig. 11, which take the electrical energy at 1150 volts and step it up to 33,000 volts, at which pressure it is transmitted to the Waterbury station over a duplicate

transmission line of 4/0 aluminum wire on wood poles, there being two banks of transformers, with one spare.

The stage of the water in the Housatonic River governs the operation of these two plants. If the water is sufficient to drive all of the six generating sets, the steam-turbine plant is relieved of much of its load, which permits of cutting out some of the boilers, turbines and generators until such time as the state of water at the hydro-electric plant demands the operation of additional steam units to maintain the maximum output of electrical energy.

Although these two stations are about 32 miles apart, they work in parallel, signals for cutting machines in and out of service being given by illuminated disks at the switchboard.

Turbine Driven Centrifugal Pump of Large Capacity

A steam-turbine-driven centrifugal pump of 100,000,000 gal. per day capacity, is to be installed in the Ross pumping station of the Pittsburgh water-works by the DeLaval Steam Turbine Co., of Trenton, N. J.

It is reported that this will be the largest steam-turbine-driven centrifugal pump ever built in this country; the rated capacity is 100,000,000 gal. per day against a total head of 56 ft.

The pump is guaranteed by the builders to show a duty of 115,000,000 ft.-lb. per 1000 lb. of dry steam, all steam used by the condensing equipment being charged to the main unit.

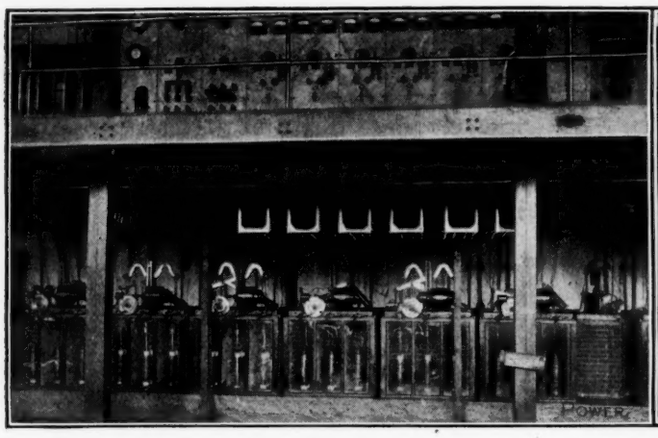

FIG. 10. OIL SWITCHES AND SWITCHBOARD

FIG. 11. TRANSFORMER ROOM

EQUIPMENT OF THE WATERBURY AND BULL'S BRIDGE, CONN., POWER PLANTS

No.	Equipment	Make	Application	Kw.	K.v.a	Volts	Phase	Cycles	Amp. per Terminal	Type	R.p.m.	Size	Pressure lb.	Hp.	
1	Steam turbine	Curtis	Main unit	3000	..	....	..	..	..	...	1800	..	175	..	General Electric Co.
2	Steam turbines	Westinghouse	Main units	..	1500	....	..	..	..	...	3600	..	175	..	Westinghouse Machine Co.
1	Steam turbine	Kerr	Circ. pump	..	..	....	..	..	..	...	970	..	175	125	Kerr Turbine Co.
2	Steam turbines	Kerr	Circ. pump	..	..	....	..	..	..	...	1750	..	175	25	Kerr Turbine Co.
2	Steam turbines	Westinghouse	Exciter units	..	..	....	..	..	..	...	1800	..	175	..	Westinghouse Machine Co.
2	Steam turbines	Terry	Fans	..	..	....	..	..	..	...	..	..	175	150	Terry Steam Turbine Co.
2	Generators	A.C.	Main units	3000	..	2,300	3	60	837	A.T.B.	1800	..	..	..	General Electric Co.
2	Generators	A.C.	Main units	..	1500	2,300	3	60	373	...	3600	..	..	..	Westinghouse Electric & Mfg. Co.
2	Generators	D.C.	Exciters	100	..	125	..	..	800	...	1800	..	..	..	Westinghouse Electric & Mfg. Co.
1	Motor	D.C.	Blower Fans	..	..	600	..	..	72 143	...	480 960	..	..	50 100	General Electric Co.
2	Motors	Induction	Converters	..	..	351	3	60	200	R	600	..	..	30	General Electric Co.
1	Motor	D.C.	Gen. drive	..	..	550	..	..	290	M.P.	450	..	..	180	General Electric Co.
2	Motors	Induction	Cooling Fans	..	..	650	3	60	14	I	..	..	..	7.5	General Electric Co.
1	Condenser	Jet	Large turbine	..	..	....	..	..	..	...	..	20"	..	..	Alberger Pump & Condenser Co.
2	Condensers	Jet	Small turbines	..	..	....	..	..	..	...	..	12"	..	..	Alberger Pump & Condenser Co.
8	Boilers	Water tube	Steam gen.	..	..	....	..	..	..	...	..	..	..	500	Bigelow Co.
8	Stokers	Taylor	Boiler furnaces	..	..	....	..	..	..	...	..	..	..	..	American Engineering Co.
8	Superheaters	Foster	Sup. steam	..	..	....	..	..	..	...	..	..	..	..	Power Specialty Co.
1	Pump	Dry air	Jet condenser	..	..	....	..	..	..	...	..	12x22x15"	175	..	Alberger Pump & Condenser Co.
2	Pumps	Dry air	Jet condensers	..	..	....	..	..	..	...	..	8x20x12"	175	..	Alberger Pump & Condenser Co.
1	Pump	Smith-valle	River water	..	..	....	..	..	..	...	..	14x12x12"	175	..	Platt Iron Works.
1	Pump	Duplex	Returns	..	..	....	..	..	..	...	..	4½x2½x4"	175	..	Henry R. Worthington.
1	Pump	Duplex	Oil system	..	..	....	..	..	..	...	..	6x7½x6	175	..	Henry R. Worthington.
4	Pumps	Duplex	Boiler feed	..	..	....	..	..	..	...	..	12x7x18"	175	..	Wilson-Snyder Mfg. Co.
3	Fans	Forced draft	.....	..	..	....	..	..	..	...	..	..	..	..	Sturtevant Co. B. F.
4	Fans	Induced draft	.....	..	..	....	..	..	..	...	..	12	..	..	Massachusetts Fan Co.
4	Regulators	Balanced draft	Boiler furnace	..	..	....	..	..	..	...	..	..	..	..	The Engineer Co.
1	Heater	Cochrane	Feed water	..	..	....	..	..	..	...	..	..	..	..	Harrison Safety Boiler Works.
1	Heater	Hoppes	Feed water	..	..	....	..	..	..	...	..	..	..	..	Hoppes Mfg. Co.
1	Weigher	Wilcox	Feed water	..	..	....	..	..	..	...	..	..	..	..	Wilcox Engineering Co.
2	Blowers	Fan	Transformers	..	..	....	..	..	..	...	..	..	..	..	Buffalo Forge Co.
1	Converter	D.C.	Generator	..	..	200	..	..	600	M.P.	450	..	..	..	General Electric Co.
2	Converters	Rotary	A.C.	1000	..	600	6	60	1667	H.C.	600	..	..	..	General Electric Co.
2	Converters	Rotary	A.C.	500	..	600	6	60	833	H.C.	600	..	..	..	General Electric Co.
3	Transformers	Air cooled	Trans. lines	600	667	33,000 2,300	1	60	..	...	..	..	½ oz.	..	Westinghouse Electric & Mfg. Co.
3	Transformers	Air cooled	Trans. lines	600	..	33,000 2,300	1	60	..	A.B.H.	..	..	½ oz.	..	General Electric Co.
6	Transformers	Air cooled	Trans. lines	500	..	33,000 440	..	60	..	A.B.	..	..	½ oz.	..	General Electric Co.
7	Transformers	Constant current	Arc circuits	62	..	2,200	..	..	6.6	R.P.	..	..	..	..	General Electric Co.
9	Transformers	Oil cooled	Trans. lines	..	300	33,000	..	60	..	H	..	..	..	..	General Electric Co.
1	Crane	Hand operated	Trans. room	..	..	6000	..	..	..	...	..	20,000 lb.	..	..	Whiting Foundry Equipment Co.
1	Crane	Hand operated	Turbine room	..	..	....	..	..	..	...	..	70,000 lb.	..	..	Brown Hoisting Machine Co.
6	Turbines	Hydraulic	Gen. units	..	..	....	..	..	..	...	400	..	..	2000	S. Morgan Smith Co.
6	Generators	A.C.	Main units	1000	..	1,150	..	..	503	...	400	..	..	..	General Electric Co.
6	Governors	Hydraulic	Water turbines	..	..	....	..	..	..	D	350	..	..	..	Lombard Governor Co.
2	Turbines	Hydraulic	Exciter set	..	..	....	..	..	..	...	..	..	..	..	S. Morgan Smith Co.
2	Generators	D.C.	Exciters	..	..	125	..	..	600	H	550	..	..	..	General Electric Co.
1	Motor	Induction	Exciter	..	..	1,150	3	60	52	C.C.L.	530	..	..	100	Westinghouse Electric & Mfg. Co.
2	Governors	Hydraulic	Exciter turbine	..	..	....	..	..	..	B	..	..	..	..	Lombard Governor Co.
9	Switches	Oil break	Trans. lines	..	..	....	..	..	..	C.A.	..	..	..	..	General Electric Co.
5	Transformers	Oil cooled	Trans. lines	850	..	1,150 33,000	..	60	..	...	..	..	..	..	General Electric Co.

The Balanced Draft System of Furnace Regulation

This system of draft control is applied to boiler furnaces to so regulate the supply of air and exhaust of gases that a substantially uniform or atmospheric pressure is maintained in the furnace for all rates of combustion. By its use, the air supplied to the furnace can be regulated to just the proper amount required for the maintenance of the desired rate of combustion. It also is claimed to increase the capacity and the efficiency of both the furnace and the boiler, and permits the use of the cheaper fuels.

Other advantages claimed for it are increased life of the boiler and setting, and reduction in maintenance and repair expenditures, due to the elimination of strains caused by unequal expansion and contraction, and the disintegration of furnace linings which follows as a consequence.

Referring to Fig. 1, it will be seen that the ashpit is connected to an air duct leading to an engine-driven air blower. The position of the uptake flue damper is controlled by a regulator, as shown in Fig. 1, and illustrated in detail inFig . 2. The regulator is belt driven from the fan engine, and the worm-shaft *A*, with the aid of suitable mechanism, oscillates the pawls *FF* backward and forward. The shield *N*, which oscillates with the pawls, prevents them from engaging with the ratchet wheels as long as the disk *U* oscillates with the shield, which it does normally.

The escapement is controlled by a Bourdon tube acting through the lever and the rod *T*. When the steam pressure is above normal, the left-hand side of the escapement is raised, engaging the disk *U* and preventing the shield *N* from moving to one side of its central position. The pawl on this side then engages the teeth of the ratchet wheel, turning it, and this motion is communicated by a worm gear to an operating lever which, through its connection, operates the damper in the corresponding direction.

The motion of the operating lever causes a compensator cam to turn, moving the outer end of the lever *S* in such a direction that the rod *T* is moved in a direction opposite to that which the Bourdon tube moved it. This regulator is said to be so sensitive that $\frac{1}{5}$-lb. variation

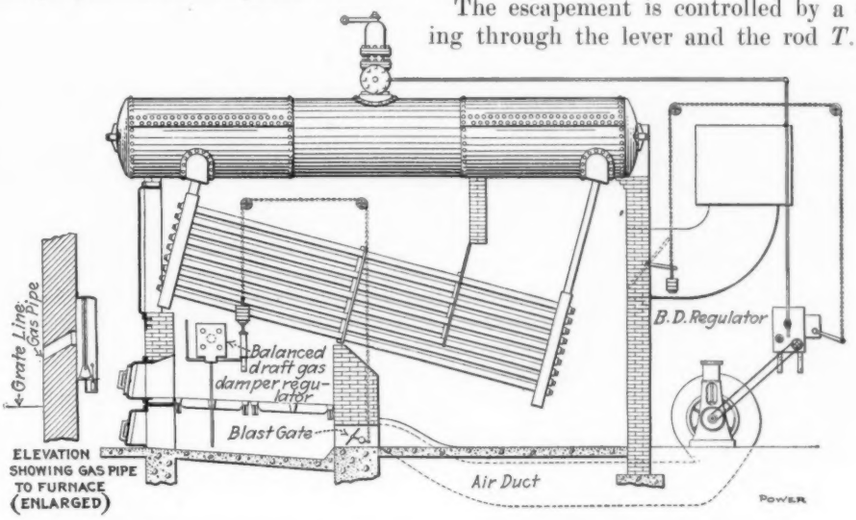

FIG. 1. DIAGRAMMATIC VIEW OF CONTROLLING APPARATUS

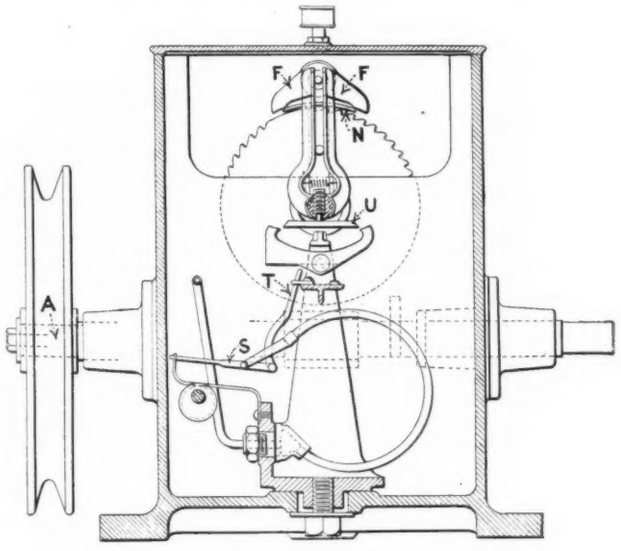

FIG. 2. SIDE AND END SECTIONAL VIEW OF B. D. REGULATOR

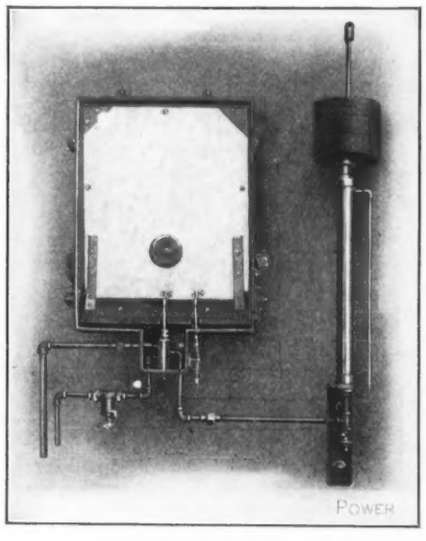

FIG. 3. REGULATOR COVER REMOVED

in steam pressure is all that is necessary to effectively operate it.

Figs. 3 and 4 show two views of the low-pressure regulator, which is operated by the pressure of gases in the furnace. It is connected to the furnace, above the grate by an opening in the back, as shown in Fig. 5. The front cover plate has four holes through which the atmosphere exerts its pressure against the outer surface of the regulator plate. This plate is made of heat-resisting material and is mounted on hardened-steel knife-edges; it is

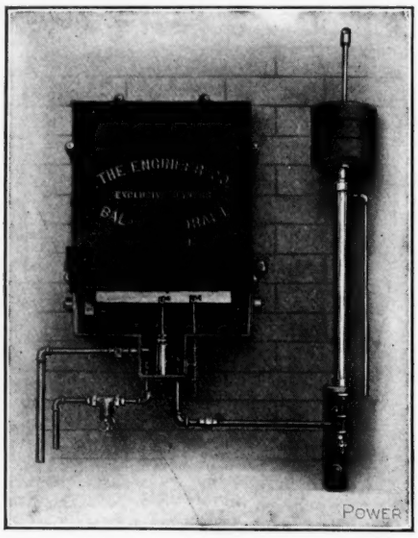

FIG. 4. REGULATOR COVER IN PLACE

weighted below the point of support. An adjustable weight is placed above the point of support, which when adjusted brings the center of gravity of the plate in the axis through the knife-edges. The plate then remains neutral in any position, and gravity will not have any tendency to turn it.

are practically frictionless, a difference in pressure between the furnace gases and the atmosphere of less than $\frac{1}{100}$-in. water gage is said to effectively operate this regulator.

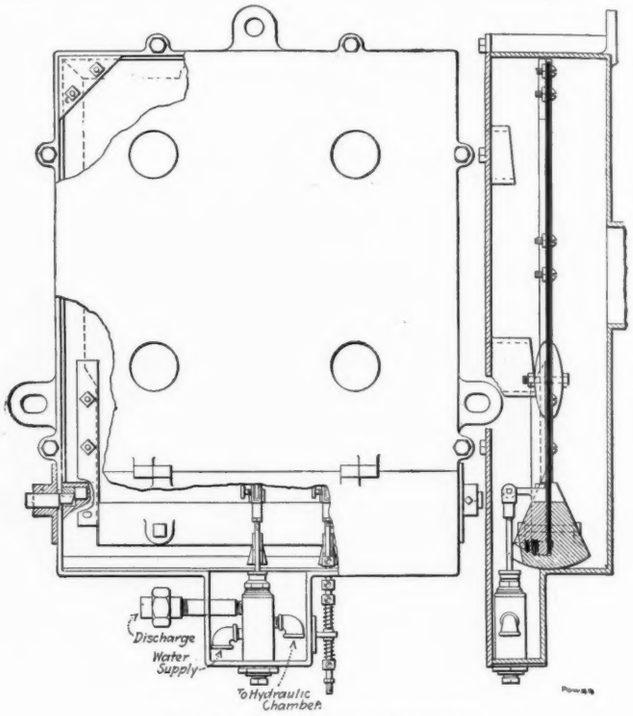

FIG. 5. DETAILS OF DAMPER

The action of the apparatus is as follows: Assuming that a steam pressure of 150 lb. is to be maintained, the B. D. regulator is so adjusted that the escapement is held in its neutral position when this pressure is exerted on the Bourdon tube. An increase of pressure beyond 150 lb. causes the mechanism to operate, moving the lever arm connected with the uptake damper, in the

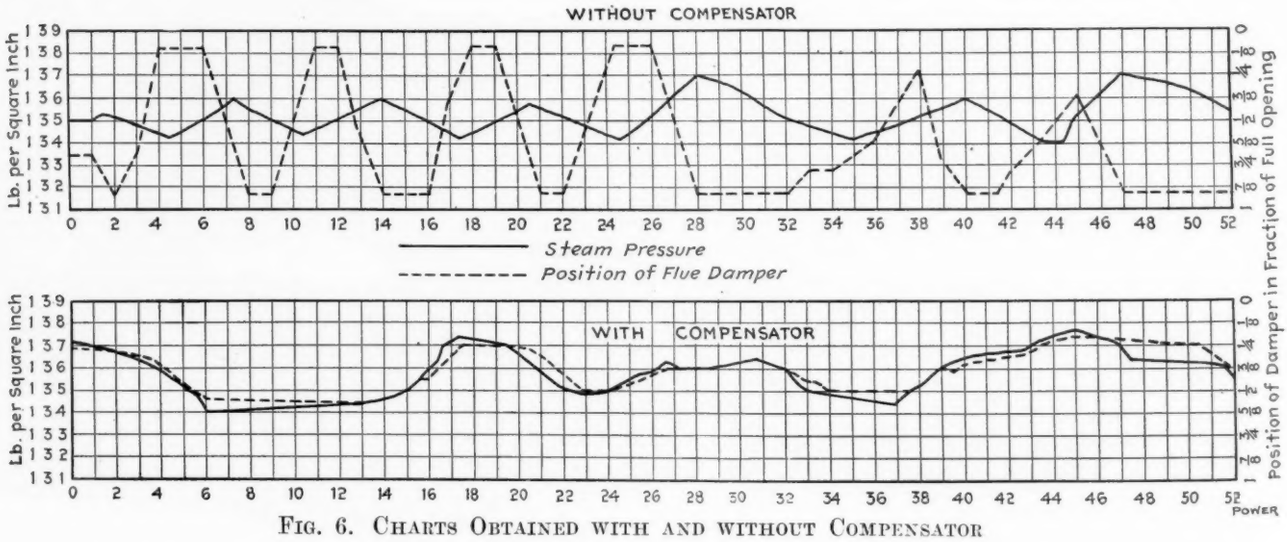
WITHOUT COMPENSATOR
Lb. per Square Inch
139
138
137
136
135
134
133
132
131
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Steam Pressure
Position of Flue Damper
Position of Damper in Fraction of Full Opening
1 15/16 7/8 13/16 3/4 11/16 5/8 9/16 1/2 7/16 3/8 5/16 1/4 3/16 1/8 1/16 0
WITH COMPENSATOR
POWER

FIG. 6. CHARTS OBTAINED WITH AND WITHOUT COMPENSATOR

A small pilot valve, operated by the motion of the plate, admits water under pressure to an operating cylinder, the piston of which moves the blast-gate damper in the air duct, Fig. 1. As the gas pressure exerted on the face of the plate does not have to overcome any action of gravity on the plate, and as the knife-edge bearings

direction to close the damper. This causes an increase of pressure of the gases in the furnace, which actuates the regulator plate of the gas-damper controller, moving it outward and operating the pilot valve to admit water to the water cylinder, the piston movement of which causes the damper in the air duct to move toward its

closed position, which reduces the volume of air supplied to the ashpit.

The air damper continues to move toward its closed position, until the supply of air is so reduced that atmospheric pressure is again attained in the furnace. Thus a constant relation between the amount of opening of the air damper and that of the uptake flue damper is maintained. The rate of combustion is controlled by the B. D. regulator, and the draft is balanced by the gas-pressure regulator.

Due to the action of the compensator on the B. D. regulator, a very slight variation of steam pressure will cause a proportionately slight movement of the operating lever, and so long as the steam pressure remains constant at any point within the range of the regulator, the operating lever will remain stationary, in the position corresponding to the existing pressure.

In Fig. 6 are two sets of curves obtained with the B. D. regulator, without and with the compensator. The steam pressure is shown by the heavy line on the scale at the left. The position of the damper is shown by the dotted line, on the scale at the right. Both charts indicate that the total steam variation does not exceed 3 lb.

In the upper chart, the spaces inclosed by the dotted line above the steam line, reveal a condition where a rate of air supply exists in excess of that required for the average rate of combustion. The spaces inclosed by the dotted line below the steam-pressure line show a condition in which a deficient quantity of air is supplied. The average of these excesses and deficiencies gives the average rate of air supply which maintains the steam pressure uniform, but at a considerable loss in furnace efficiency. The ideal point of regulation is where the two lines representing the steam pressure and the damper movement coincide. The lower curve shows that this ideal is approached very closely when using the B. D. regulator.

The "Balanced Draft" system, as described above, treats a group of furnaces as one big furnace, regulating the total output from the group, but provides no automatic means for controlling each one of the group in reference to the others. Embury McLean, the inventor, has recently perfected a system of automatic control for a group of boiler furnaces whereby the output from each boiler will always maintain a fixed relation to the output of the group of boilers. This means that each boiler will be compelled by automatic means to do its *pro rata* share of the work. For very large plants, the same system of regulation can be applied in a different way to regulate the total output of the plant, by automatically cutting in or cutting out boilers, so that all of the boilers that are "in" are operating at their maximum capacity, which means maximum efficiency, and the boilers which are "out" are operated at combustion rate just sufficient to keep the boiler and setting hot to prevent condensation.

This new method of regulation the inventor considers as fundamental with reference to the regulation of each of a group of boilers, as his "Balanced Draft" system is in regard to the regulation of a single boiler, or a group of boilers treated as a unit.

All of Mr. McLean's United States patents covering furnace regulation are owned by The Engineer Co., 50 Church St., New York City.

Draft and Boiler Capacity and Efficiency

Tests in connection with the Blonck boiler-efficiency meter, described in the Dec. 24 issue, bring out some interesting points in the relation between draft, capacity and efficiency.

The problem in practical boiler operation is to secure capacity and efficiency simultaneously. It is well known that the CO_2 content is a reasonably good index to combustion efficiency but absolutely no guide to the capacity being developed. Hence, when CO_2 alone is depended upon, it is often found that when high CO_2 has been attained, the rate of steam output has fallen off and, to restore the proper rate quickly, it is necessary to sacrifice economy.

Most economical results are secured with a white fire and evenly covered grate, conditions conducive to high CO_2.

It is difficult for even a well experienced fireman to know simply by observation when these conditions prevail to a maximum extent. And even if good combustion conditions do prevail, it is especially difficult to be certain that the boiler is developing its proper portion of the load. The draft distribution, however, is a key to both efficiency and capacity.

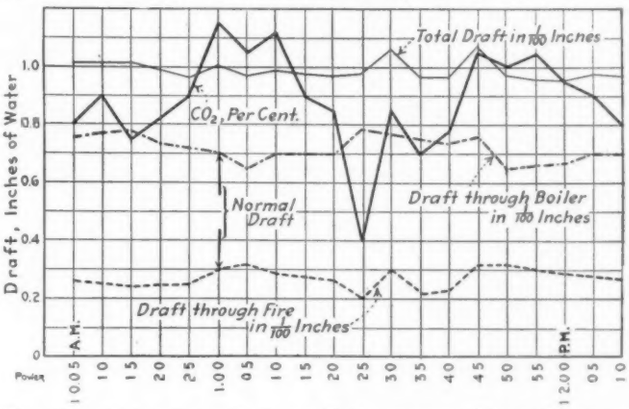

FIG. 1. GRAPHICAL LOG OF TEST UNDER FULL LOAD OF 375-HP. STIRLING BOILER WITH CHAIN GRATE

With the boiler operating at its normal rate (that is to say, with a fixed total effective draft) a decrease in the normal resistance of the fire produces an increase in the drop in draft through the boiler and a loss in efficiency due to excess air. An increase in the resistance of the fire causes a decrease in the drop through the boiler and a reduced rate of steaming; if the increase is extreme there is also an efficiency loss due to incomplete combustion.

These points are remarkably well illustrated in the accompanying figures when due consideration is given to the difficulty of synchronizing the draft readings and the CO_2 analyses and the probability of error in the analyses themselves.

In Fig. 1 the total draft remained practically constant from 10:05 to 11:25 o'clock, the greatest variation being but 0.05 in. The furnace draft, however, changed from 0.26 to 0.30 in. and the draft through the boiler from 0.76 to 0.71 in., producing a change in the CO_2 content from 8 to 11.5 per cent. Between 11 and 11:10 a.m. an apparent inconsistency exists as the furnace draft increases, the boiler draft decreases and the CO_2 falls

while logically it should rise. From 11:10 to 11:20 a.m. the total and boiler draft are constant and the furnace draft and CO_2 fall. Between 11:20 and 11:25 a.m. the furnace draft drops markedly, the boiler draft increases proportionately, and the CO_2 falls from 8.5 to 4 per cent., showing that the furnace was flooded with air. As the furnace draft rises from 0.23 at 11:40 to 0.32 per cent. at 11:45 o'clock the CO_2 increases from 7.8 not changed materially, the steam output was cut down as is clearly shown by the high furnace and low boiler draft.

Fig. 3 brings out the effect of the changes in total draft on the rate of steaming. The instantaneous flow-meter readings are erratic because the boiler was discharging to the same header with a number of other boilers and the feed regulation was adjusted largely by guess work.

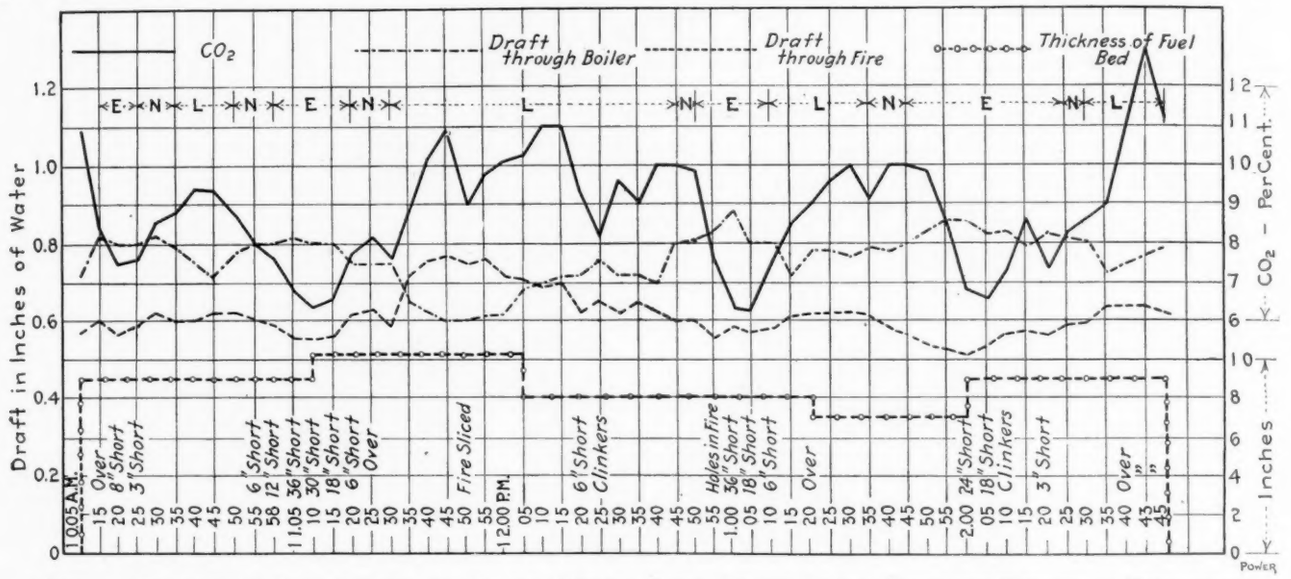

FIG. 2. GRAPHICAL LOG OF TEST OF 500-HP. BOILER WITH CHAIN GRATE, SHOWING EFFECT OF THICKNESS OF FUEL BED

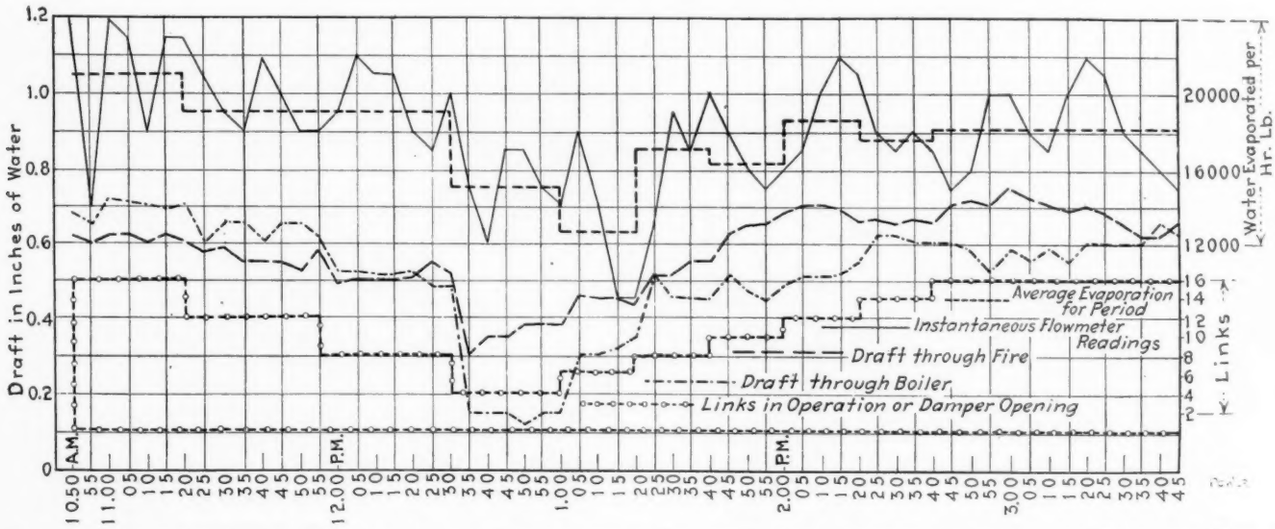

FIG. 3. GRAPHICAL LOG OF TEST OF 500-HP. BOILER WITH CHAIN GRATE, SHOWING EFFECT OF VARIABLE LOAD

to 10.5. At the same time, the boiler and total draft readings increase, indicating that output has increased simultaneously with the improvement in combustion efficiency.

The influence of the thickness of the fuel bed on the draft distribution, steam output and efficiency is brought out in Fig. 2. The effect of a "short" fire is also shown. At 11:05 and again at 1 and 2 o'clock the fire was 2 or more feet short, reducing the resistance of the fuel bed to the lowest point, increasing the draft through the boiler, due to excess air, and, hence, markedly reducing the CO_2 content. Between 11:10 and 12:05 o'clock the fuel bed was thickest and even and, because the total draft was Nevertheless, it may be seen that the average evaporation for a given period follows quite closely the variations in draft.

It will also be noticed that when evaporating 21,000 lb. of water per hour between 10:05 and 10:20 a.m. the furnace draft was about 0.6 in. and the boiler draft about 10.7 in., whereas at the end of the test when an effort was made to bring back the rate to 21,000 lb. per hr., only the 18,000-lb. rate was attained because the fuel bed had become badly choked, thus increasing the furnace draft to over 0.7 in. and reducing the boiler draft to less than 0.6 and, hence, reducing the rate of combustion correspondingly.

ELECTRICAL DEPARTMENT

Primer of Electricity

By Cecil P. Poole

Dynamo and Motor Field Magnets

In most of the previous sections of the Primer, it has been assumed that the field magnet of a dynamo or motor has only two poles, and where illustrations were used they all showed the simple horseshoe type of magnet represented in Fig. 132, which was formerly the only type built. Except very small machines and some of special design to suit peculiar conditions, however, all modern dynamos and motors are made with more than two magnet poles; such machines are called "multipolar."

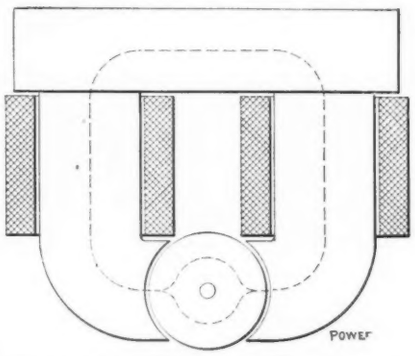

Fig. 132. Bipolar Field Magnet with Vertical Cores

If the reader remembers the discussion of the electromagnet in one of the early installments of this series, he will doubtless wonder how one magnet can have more than two poles. In cannot; but two or more magnets can be combined in one structure, with the result that there are four, six, eight or some other even number of poles, and that is what is done.

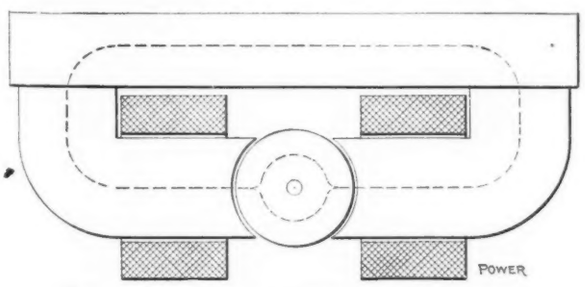

Fig. 133. Bipolar Field Magnet with Horizontal Cores

Figs. 133 to 136 inclusive illustrate the development of the modern four-pole magnet frame from the original "horseshoe" type of Fig. 132. The only difference between Fig. 132 and Fig. 133 is that the parts of the magnet which are surrounded by the coils are vertical in the one and horizontal in the other. The parts surrounded by coils are the "cores" of the magnet. Retaining the horizontal cores of Fig. 133 and dividing the connecting yoke into two parts, one above and the other below the armature, produces the type shown in Fig. 134. In all three diagrams the center of the path of the magnetic flux, or lines of force, is indicated by the dotted lines.

It will be noticed that in all cases the flux divides into two paths through the armature core, one-half going on each side of the shaft hole. In Fig. 134 it does the same thing in the yoke, and as each branch of the yoke carries only one-half of the total flux the cross-section is one-half as large in this form as in the simpler forms shown in Figs. 132 and 133.

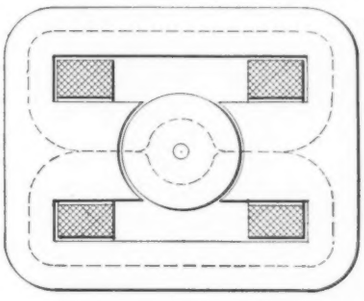

Fig. 134. Bipolar Magnet with Divided Yoke

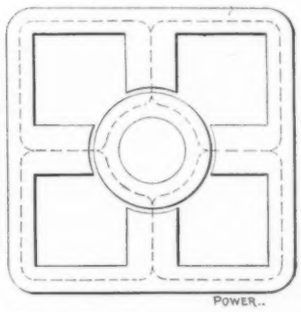

Fig. 135. Four-pole Development from Fig. 134

The next step is from the bipolar form of Fig. 134 to the four-pole form of Fig. 135. This is made by simply adding two poles and cores midway between the first two and making the outer frame (yoke) square instead of oblong to provide space for the lengths of the added cores. It will be noticed that the four-pole yoke and each magnet core are much thinner than those of the bipolar machine; this is also true of the armature core. The reduction in the thickness of the magnet cores does not result in a corresponding reduction in total weight because there are twice as many thin cores. But the reduction in the thickness of the yoke and that of the armature core effects a reduction in weight that is almost proportional, and this is one of the principal advantages of multipolar construction.

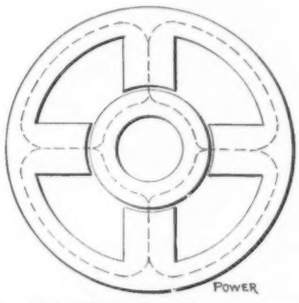

Fig. 136. Modern Type with Circular Yoke

Relation between Number of Poles and Cross-section

A little reasoning will make it clear why reduction of the thickness of the cores and yoke is made possible by increasing the number of poles. Suppose that the total magnetic flux through each magnet core of the two-pole machine in Fig. 134 were 1,200,000 lines of force and the magnetic density were 80,000 lines per square inch in the yoke, the magnet cores and the armature core. As the flux splits into two parts in the yoke, 600,000 lines pass each way from pole to pole; therefore the cross-section of the yoke must be 7½ sq.in. In each magnet core the cross-section must be 15 sq.in. and the armature core must have 7½ sq.in. of cross-section to carry 600,000 lines (one-half of the total flux) at the density assumed. (It is not customary to make the magnetic density the same in all parts of the circuit; that is done here for simplicity.)

Now consider the four-pole machine. With a total flux of 1,200,000 lines there will be 600,000 lines crossing each *pair* of air gaps and passing through each *pair* of

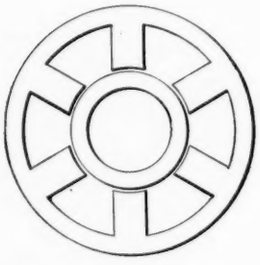

Fig. 137. Six-pole Equivalent of Fig. 136

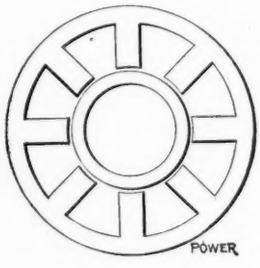

Fig. 138. Eight-pole Equivalent of Fig. 136

magnet cores. This flux of 600,000 lines per pole divides into two fluxes of 300,000 lines each in the yoke and in the armature core. In the two-pole machine the flux in the yoke and armature paths was 600,000; here it is 300,000; therefore the yoke cross-section can be made 3¾ sq.in. instead of 7½, and the armature section also reduced one-half. The magnet cores carry 600,000 lines each instead of 1,200,000 and the cross-section therefore may be made 7½ sq.in. each, instead of 15. It will be found that Fig. 135 and all the succeeding diagrams are so proportioned as to make the thicknesses of the cores and yoke correspond to the figures just given.

Four-pole machines are not usually built with yokes of square outline as in Fig. 135; this form is shown here to make the step from two-pole to four-pole construction as simple as possible. In general, the yoke is made of circular form, as in Fig. 136.

The same reasoning as to the relation between the number of poles and the cross-section of each magnetic path in a machine applies to dynamos and motors having more than four poles. For the same output, speed and magnetic densities, the cross-sections of a six-pole machine are one-third those of a bipolar machine (or two-thirds those of a four-pole machine) and the cross-sections of an eight-pole magnet and armature are one-fourth those of a bipolar, one-half those of a four-pole, or three-fourths those of a six-pole machine. Figs. 137 and 138 are to the same scale as the preceding diagrams and with them furnish an accurate comparison of the sizes of magnet frames and armature cores with different numbers of poles.

In all cases here represented, the differences in cross-section have been put into the thickness of each part to make them visible. For example, the thickness of the yoke in Fig. 135 is made one-half that in Fig. 134 to indicate a cross-section one-half as great. In actual machines this is not customary; the greater the number of poles, the shorter is the machine, measured along the shaft, and there are not as great differences in the radial thickness of the yoke and armature core and the transverse thickness of the magnet cores as are here shown.

In view of the great reduction in the cross-sections and therefore the weights of machines due to increasing the number of field-magnet poles it would seem desirable to make all dynamos and motors with a large number of poles, to save material. There are other things to be considered besides weight, however, and most of these make either the bipolar or the four-pole form preferable to a large number of poles. Only when lightness is the most important consideration, or when good commutation or convenience in handling the armature winding make it necessary, are more than four poles used. In general, large machines are built with six or eight poles because of one or both of the points last mentioned.

Distribution of Magnetizing Forces

The magnetic relations between the different cores of a multipolar machine are a little hard to understand at first. Probably the easiest way of considering them is

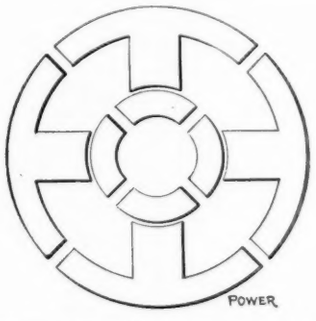

Fig. 139. Distribution of Magnetizing Forces

to say that each magnet coil supplies flux through the core it surrounds and the corresponding airgap, the yoke halfway between that core and the next one on each side of it, and the same relative part of the armature core. For example, in a four-pole machine, imagine the frame and armature cut into four equal parts, as in Fig. 139, and each part magnetized by the coil included with that part.

Another view is that each pair of poles constitutes one magnet and that the several magnets are connected by their yokes and share the connecting paths equally. This is not as logical a view as the first one because the flux in any one core actually divides between the two cores on each side of it, so that the whole system of cores is "tied together" magnetically as well as mechanically.

GAS POWER DEPARTMENT

Classification of Oil Engines

By Oscar P. Ostergren

The present development of the oil industry is due, first, to the art of drilling wells, which has made it possible to reach successfully and economically depths of from 4000 to 5000 ft., and second, to a better knowledge of geological conditions of oil-bearing strata.

In 1908 the U. S. Geological Survey reported 8450 square miles of oil territory in the United States alone, leaving an estimated possible future production of from

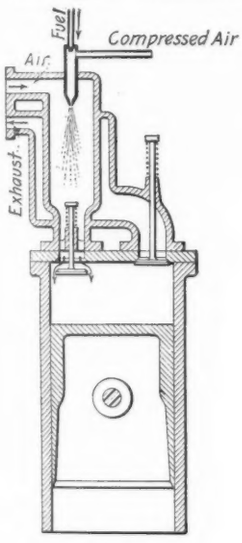

FIG. 1

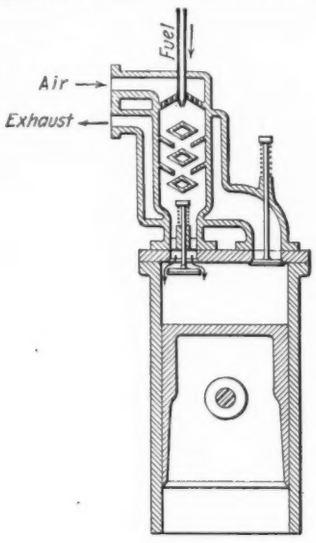

FIG. 2

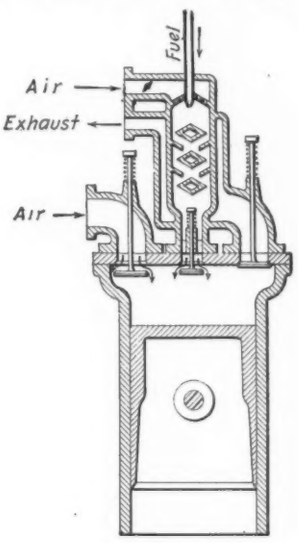

FIG. 3

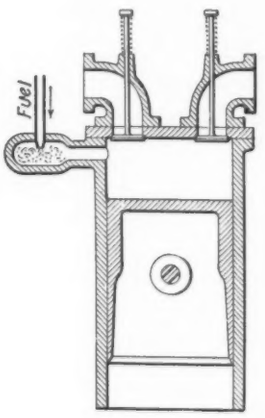

FIG. 4

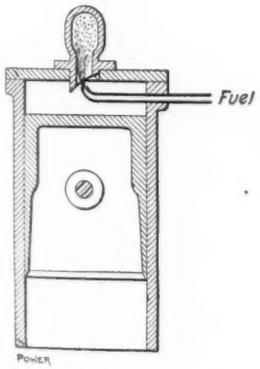

FIG. 5

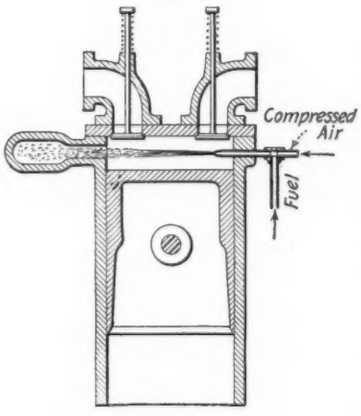

FIG. 6

Typical Vaporizing and Mixing Arrangements

10,000,000,000 to 24,500,000,000 bbl. These figures refer only to the practically proven oil territory in the United States and may be considered conservative. Outside of this it is, of course, impossible to say what the actual production will be.

Crude petroleum consists principally of various combinations of hydrogen and carbon with comparatively small amounts of nitrogen, oxygen and sulphur. Nitrogen and oxygen and any incombustible residue of ash may be classified as inert impurities. Sulphur, though combustible, has a low heat value and is otherwise injurious. Taking hydrogen and carbon as the principal constituents, it is found that those oils which are rich in the former element are of light specific gravity as compared with those rich in carbon.

The range in specific gravity of California crude oil may be taken as from 0.84 to 1 or from 10 to 36 deg. Bé. It is evident that, other things being equal, oils rich in hydrogen will contain more heat units per pound than those rich in carbon, pure hydrogen having a heat value of 62,000 B.t.u. per lb. as compared with 14,650 B.t.u. per lb. of carbon.

The extended use of the gasoline engine has indirectly given a great impetus to the oil industry and incidentally to the manufacture of heavy oil engines. The problem of utilizing heavy hydrocarbons, such as kerosene and fuel oil or even crude oil, so as to produce an explosive mixture has been such a difficult task that for many years no effective engine of this class was placed on the market.

Through numerous experiments it was seen that to get a proper mixture the oil must first be vaporized by the aid of high temperatures. Indeed, the problem resolved into a gradual and simultaneous heating of both fuel and air, gradually adding more air to the mixture up to the time of explosion. Upon the ability to carry out this process or approximate it in an engine, hinged the success of the latter, and many have been the failures of otherwise meritorious inventions because the requirements for the foregoing process had not been observed. Thus, the vaporizer must not be too hot, as that would cause decomposition of the fuel and deposits of carbon; nor must the mixture be allowed to cool down, as that would cause precipitation of oil in the passages, valves and cylinder, likewise causing deposits of carbon.

The problem of suiting the mixture to the load was

also important. Typical arrangements that have been tried for vaporizing and mixing are shown in Figs. 1 to 6. In Fig. 1 the liquid fuel is mixed with and broken up by an air jet under 10 to 25 lb. pressure, entering the vaporizing chamber in a finely divided spray. The bulk of air mixes during the suction stroke with the preheated air and vaporized fuel as it is drawn through the vaporizer and enters the cylinder where it is compressed and ignited the same as in a gas or gasoline engine.

It will be noticed that this vaporizer must be heated at first with a torch, or the engine must be started with some lighter oil, such as gasoline. After starting, the heat of the exhaust gases will be sufficient to keep the vaporizer hot.

Figs. 2 and 3 represent vaporizers commonly used in connection with ordinary gas or gasoline engines for the utilization of heavy oils. Fuel vapors are produced by precipitating the liquid fuel on a series of baffles inside the vaporizer. In Fig. 2 the vapors are absorbed by the entire air current which traverses the vaporizer during the suction stroke, while in Fig. 3 only a part of the air is allowed to pass through the vaporizer, the bulk of the air being admitted to the cylinder by an independent valve.

The principle represented in Figs. 4 and 5 is extremely simple. In Fig. 4 the fuel is injected into the vaporizing chamber, which for starting has been heated to incandescence by a torch; after the engine has been started the vaporizer is maintained incandescent by the heat of combustion and compression. During compression air enters at high speed through the contracted opening and mixes with the vapors therein contained until at the end of the stroke the mixture attains the proper proportion and temperature for explosion. The sides of the chamber must be hot enough to ignite the charge, but not hot enough to decompose the fuel.

In Fig. 5 the method of introducing the fuel is somewhat modified. The oil is forced in by means of a governor-controlled force pump through a very small orifice. In the form of a fine spray it impinges on a baffle or extension of the bulb and a part of the fuel is deflected into the latter or a suitable pocket. By this arrangement it is quite feasible to vary the amount of the fuel charge within a considerable range.

In Fig. 6 the fuel is injected right into the cylinder by means of a high-pressure air jet. This jet is so directed that a considerable part of the fuel vapor will enter a hot chamber or sometimes impinges on a hot plate. In this case the fuel admission is timed and begins a few degrees before the piston is at the end of the compression stroke. By this arrangement the danger of premature ignition is entirely removed. Not only is it possible to carry the compression much higher than in the former cases, but inasmuch as the fuel is gradually consumed as it enters the highly compressed air the thermal cycle is greatly improved for all conditions of load. This type of engine might be considered as a link between the types formerly described and the Diesel.

With the exception of the last type those mentioned are not as efficient thermally as a gas engine. The difficulties which prevent any extended improvement are to be found in their method of vaporization. In each case, it will be seen the air has to be preheated to a certain extent. This is poor practice; first, because preheating decreases the charge in weight and also the capacity of the engine, second, the range of compression is limited on account of the danger of premature ignition due to additional compression temperature. The necessity of heating the vaporizer before starting or having to start the engine on gasoline is also a drawback.

Case 6 is superior to the others in all respects, except that it is more complicated and employs preheating. The range and nicety of governing is also greatly limited in cases 1 to 5 by the fact that at light loads the mixture when weakened to a certain extent abruptly ceases to explode, no matter to what temperature it is subjected. The average fuel consumption in cases 1 to 5 is about 1 lb. per b.hp.-hr., corresponding to about 15 per cent. thermal efficiency. Attempts have been made to attain high compression pressures by lowering the temperature thereof by the injection of water during the compression period. In this way it has been proved that the compression can be carried considerably higher, and in some engines this principle is employed where hot bulb vaporizers are used.

The Diesel Group

While the principle of the Diesel engine is quite simple and has from time to time been discussed in these columns, it will only be necessary for the present purpose to give a brief outline of the scheme which is at the base of the world-wide activity now manifest since the expiration of the original Diesel patents.

This engine has the following characteristics of operation: During the compression stroke the cylinder contains only air, which is compressed to at least 450 lb., the resulting temperature reaching a point sufficiently high to ignite the liquid fuel injected (at least 1000 deg. F.). At the end of the compression stroke fuel is gradually injected by means of an air blast at a pressure about 250 lb. above that in the cylinder. This high-pressure air blast completely atomizes the fuel during the injection periods and carries its minute particles directly into the air in the cylinder, compressed and heated as mentioned, wherein they are immediately vaporized and ignited.

The progress of the fuel injection is so adjusted that combustion takes place without any material explosion or rise in pressure and is continued for about 10 per cent. of the expansion stroke, causing the development of heat to take place at approximately constant pressure for the admission period. Since the proper condition for ignition and combustion exists throughout the air body, the oil particles burn immediately after penetrating the first products of combustion and reach the fresh oxygen of which there is a large surplus, even for the maximum charge of fuel; there is no possibility of the fuel reaching the enveloping surfaces without being consumed. For this reason there is no opportunity for carbon deposits to form on the cylinder walls, and the combustion is so complete that the exhaust products are smokeless and without odor.

The average fuel consumption for the Diesel engine is less than ½ lb. per b.hp.-hr., corresponding to a thermal efficiency of about 30 per cent. or more. To this high fuel economy the Diesel engine largely owes its success in Europe, but there are also other contributing reasons.

As the compression of the air free from fuel can be carried to a pressure corresponding to an incandescent temperature, most any liquid fuel can be utilized without other accessories than the auxiliary air compressor, which furnishes the injection air, the injection and spraying apparatus, and the fuel pump. This, of course, does not

include the circulating pump for the jacket water, which is also necessary in the other types.

The Diesel engine is well adapted to work on the two-stroke cycle as the scavenging process is accomplished with air alone, a surplus of which may be used to insure a clean cylinder. No waste of fuel can take place in this connection and no backfiring.

Fig. 7 represents the position when a measured quantity of fuel, according to the load, is being deposited in space S of the injection-valve cage C by the oil pump O, the injection valve N being closed. Space S is continuously in communication with the air storage tank T into which the two-stage air compressor A delivers the air required for fuel injection at a pressure of from 750 to 1000 lb. The oil must, therefore, be delivered into space S against this high pressure, which in view of the small quantity to be delivered, requires extremely accurate work and adjustment on the oil pumps. Since the fuel and injection air come in contact while the injection valve N is still closed, it is obvious that the valve cage C, as well as the injection air, must be well cooled to prevent dangerous premature ignitions or the formation of deposits due to partial evaporation of the deposited fuel.

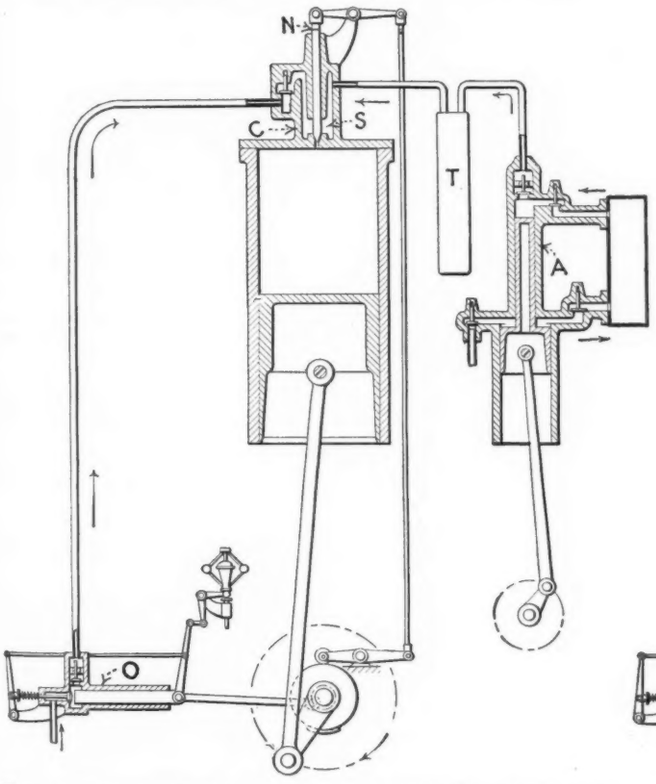

FIG. 7. POSITION WHEN FUEL IS BEING INJECTED INTO VALVE CHAMBER

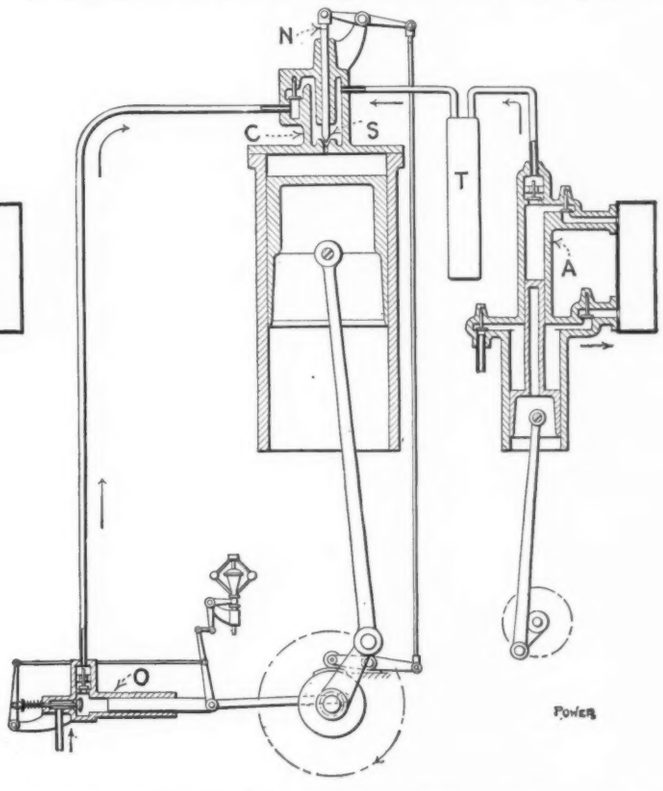

FIG. 8. POSITION WHEN FUEL IS BEING INJECTED INTO CYLINDER

Fig. 8 represents the actual injection period which starts as soon as valve N opens; the latter, therefore, controls simultaneously the admission of fuel and injection of air into the cylinder. At all loads the time of opening and closing of the injection valve N remains unchanged, that is, the period the injection valve is open is constant. Within this period a variable quantity of fuel, according to the load, is injected.

To accomplish this most satisfactorily it has been found necessary to increase the pressure of the injection air with increasing loads on the engine, that is, with increasing amounts of fuel to be injected Diesel-engine manufacturers recommend a pressure increase of about 250 lb. from light to maximum load. Since the compression in the engine cylinder is constant at all loads, this is undoubtedly due to the fact that there must be sufficient pressure to accelerate the largest charge of oil, so that it is properly atomized, on the one hand, and not enough to extinguish the ignition from the cooling effect when small charges are injected, on the other.

Summarizing, the essential features of the Diesel engine are: The air is compressed while unmixed with fuel, which permits high compression and economy of fuel. Ignition takes place at the proper time without fail and without special devices. It can operate economically within a wide range of loads and is well adapted for the two-stroke cycle. It can operate with a great variety of hydrocarbons.

In accordance with the purpose of this article the present limitations of the engine should also be set forth. It requires a high degree of workmanship in manufacture and the first cost is high in comparison with other prime movers. It is heavier per horsepower than most types of internal-combustion engines and on this account is unsuited for special purposes such as for vehicles. The features of variable pressure for the injection air adds complications to the engine or watchfulness on the part of the operator. It requires the storage of air at high pressure for starting (about 1000 lb.) and, as a whole, is very complicated. The power of one cylinder is strictly limited. All these objectionable features are strictly true, notwithstanding claims to the contrary by manufacturers and enthusiasts. But experimental work is being carried on continually and it is the writer's opinion that each of these limitations will be and are being eliminated.

REFRIGERATION DEPARTMENT

Weighing Ammonia to Determine Refrigerating Capacity

By Fred Ophüls

When testing boilers it is customary to weigh or measure both the water and the fuel fed to them during the test. The weight of water divided by the weight of the fuel used for a certain time gives the actual weight of water evaporated per pound of fuel fired, proper corrections being made for moisture in the steam, etc. It is not customary in this case to condense the steam produced by the boilers after it has passed through engines, pumps, heaters, and the machinery and apparatus and then weigh the condensate, also determine the heat carried away through the stack from the composition, weight and temperature of flue gases, add to this the heat supplied to the water to turn it into steam and allow for radiation and other heat losses, and by dividing the total quantity of heat so obtained by the heat value of the fuel per pound, determine the weight of fuel used.

For testing the performance of refrigerating machinery the method is somewhat comparable to the latter method of finding boiler economy. It is based on measuring or weighing the amount of brine cooled and the range through which it is cooled. Any errors in observing the temperatures and quantities and the losses unaccounted for will effect the accuracy of the result.

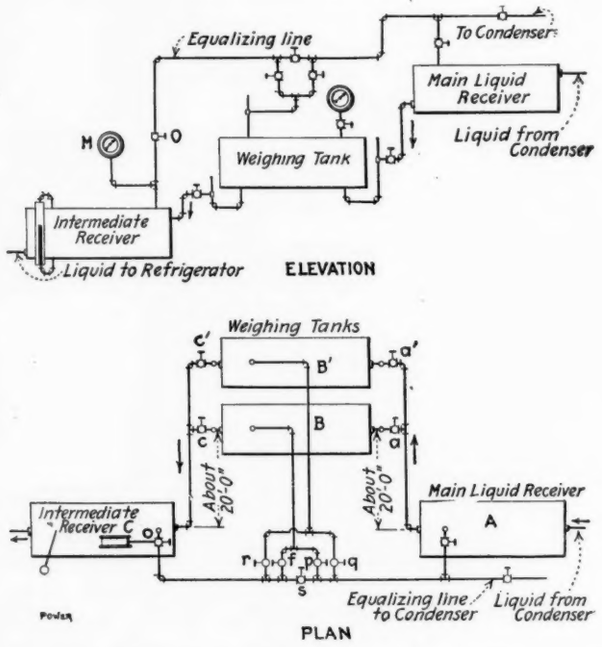

Fig. 1. Piping Connections for Weighing System

Take, for example, a case where 120 gal. of brine is circulated per minute and the temperature range of the brine is 6 deg. F., which is equivalent to 25 tons of refrigerating effect. An error of one-tenth of a degree in each of the brine readings may cause the range to be either two-tenths of one degree too high or too low. The error in that case would be 2 in 60, or about 3⅓ per cent. Increasing the number of gallons of brine circulated to 240, the brine range for the same tonnage would be only 3 deg. F. and for the same error of reading the result would be either 7 per cent. too high or too low. Further errors are introduced into the calculations by discrepancies in the brine reading itself and fluctuations in operating conditions during the intervals between readings.

Many attempts have been made to weigh the liquid anhydrous ammonia, and in this way get an accurate knowledge of the exact amount of the actual refrigerating medium circulated in a given time. The weight of ammonia circulated can be obtained with great accuracy if due care is taken in the installation and handling of the weighing apparatus.

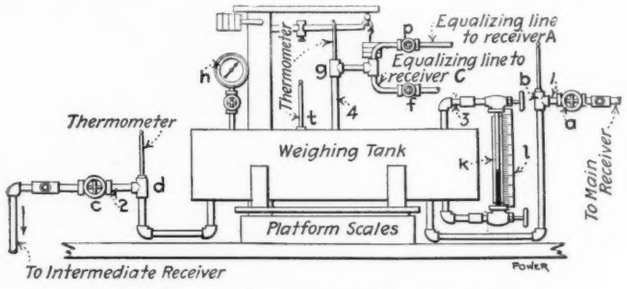

Fig. 2. Detail Sketch of Weighing Tank

Liquid anhydrous ammonia cannot be so easily handled as water or other liquids. It must be maintained under a high pressure when it is being weighed and before it enters the refrigerator, which makes the problem somewhat difficult. It is necessary that the tanks in which the liquid is stored and those in which it is weighed be joined by supply and discharge piping and by pressure equalizing lines to permit the flow of the liquid from one to the other.

It has been claimed that the equalizing lines especially are a source of error. It will be shown here that this error is small, if it exists at all, and that it can be minimized by a proper manipulation of the weighing outfit.

In Fig. 1 is shown a proposed arrangement of the ammonia receivers and the weighing tanks. For facilitating the flow of liquid from one tank to the other, the weighing tanks are placed lower than the main receiver and the intermediate receiver below the former. It may be noticed that the equalizing line is provided with the necessary valves so that each tank can be shut off from the line completely, or either one, two, three, or all four tanks equalized at one time.

Fig. 2 shows in detail the proposed arrangement of the piping, valves and instruments around the weighing tanks. It may be seen that the liquid ammonia enters the weighing tanks through pipe 1 at the right-hand end. This pipe connection is supplied with a shut-off valve *a* and a mercury well *b* with thermometer. The liquid leaves

the tanks through pipe 2, which is provided with a valve c and a mercury well d with thermometer. The equalizing pipe 4 has valves f and p and a mercury well with thermometer at g. A high-pressure ammonia gage h serves to show any undue fluctuations in pressure in the tank and the gage-glass k, to show the height of the liquid in the tank, this being read off in inches on scale l.

The intermediate receiver is also provided with a gage-glass, pressure gage and a mercury well with thermometer in the pipe leading to the expansion valves.

When the plant is adjusted and conditions are as desired for the test, close the valves c and c', Fig. 1, and allow the weighing tanks to fill, keeping the equalizing valves all open. When the weighing tanks are filled to the desired height, close off tank B entirely by shutting the valves a, f, p and c. Open the valve c' on tank B' so that the ammonia it contains can run into the lower tank C and feed the system while tank B is being weighed. The valve c' on tank B' is so manipulated that the liquid level in tank C is maintained at a fixed point marked on its gage-glass.

When tank B has been weighed, pressure gage h read and the temperatures at b and d and of the air surrounding the tank have been taken, shut valve c' on tank B' exactly on the time of taking the first reading. Close the equalizing valves r and s, so that tank B' equalizes into the line to tank A only. In case any undue pressure has accumulated in tank B, let it equalize to tank A by opening valve p for a moment and weigh it again. Then equalize tank B over to tank C and by opening valves f and o allow all the liquid you wish to take from tank B to drain as quickly as possible into tank C. Shut off tank B from the system and weigh. The difference in weight will give the pounds of ammonia discharged into tank C, after making an allowance for greater quantity of vapor in tank B, when empty than when full. The volume and weight of this vapor can be determined by calibrating the weighing tanks with ice-machine oil before connecting them into the system and by noting the temperature and pressure in the tank when testing. Each weighing tank should have a mercury well t with thermometer for this purpose.

The pipe connection 2 from tanks B and B' to tank C should be made of ample size so that the liquid in the weighing tanks can flow rapidly into tank C; in this way there is a perfect balance between the vapors above the liquid level in each tank.

Tank B' having been filled, closed off from the system and weighed while the liquid was flowing from tank B into tank C, it is ready, when tank C has been emptied to the desired point, to supply the latter with fresh liquid. To avoid a pressure drop in tank C while it is emptying, it is again equalized with tank B while the latter is being refilled.

It may be noticed that the liquid inlets are at the bottom of the weighing tanks. This precaution is taken so that no exchange of vapor can occur between them, the receiver A and the ammonia condensers. The equalizing connections from the tanks B, B' and C to tank A and the condensers are only used at the start of the test and whenever it is desired to change the pressure in these lower tanks.

By filling tank B at the same rate as tank C is emptying, the same pressure is maintained on the liquid while feeding into the refrigerator, which is desirable for good test results. As soon as tank C is empty it is completely shut off from tank B, and the liquid in tank B' is drained into C and the same manipulation gone through with as before described for tank B.

With the tanks arranged as shown in Figs. 1 and 2, and allowances made for the change in the amount of vapor in the weighing tanks when full and when empty the weights obtained should be correct. The temperatures of the liquid while entering and leaving tanks B, B' and C should be carefully observed so that any correction necessary on account of the heat leakage may be made. The heating surfaces are small as well as the temperature differences between the room and the liquid in the tanks.

A more difficult point to take care of is the quantity of liquid in the expansion side of the plant. This should be the same at the end of the test as it was at the beginning, so that the amount of ammonia weighed corresponds with the amount of ammonia actually evaporated. While the amount of ammonia in tank C can easily be brought to the proper level at the end of the test by judicious feeding from the weighing tanks and observing the liquid level, there is no practical arrangement that can be made in a refrigerating plant of any size by which the quantity of liquid ammonia can be observed in the low-pressure side either by weight or by sight glass, except in the case of a shell type or a straight-tube brine cooler. No gage glasses can be attached to double-pipe brine coolers or direct-expansion piping in the cold-storage rooms or cellars which will show the amount of liquid in the coils at any time during the test. It is, however, safe to say that when in a brine system the back-pressure temperature of the vapor at the compressor, the revolutions of the compressor, the initial and final brine temperatures and the quantity of brine being pumped through the system are all about the same at the end as at the beginning of the test, the quantity of liquid ammonia it contains

AMMONIA CIRCULATED PER MINUTE AS DETERMINED FROM BRINE WEIGHT AND TEMPERATURE RANGE AND BY WEIGHING

	Test number	1	2	3	4	5	6	7	8	9	10	11
1	B.t.u. removed from brine per min.	10,044	10,466	10,410	8028	12,192	14,410	10,298	10,252	10,640	7710	12,782
2	Abs. suc. press., lb. per sq.in.	35.23	35.35	35.73	35.46	35.51	34.51	35.43	35.14	35.00	35.41	35.21
3	Temp. of saturated vapor, deg. F.	6.68	6.82	7.28	6.96	7.01	5.66	6.93	6.58	6.40	6.90	6.65
4	Suction temp. at cooler	21.11	19.55	15.62	19.40	11.58	14.69	9.33	9.36	10.37	9.29	9.90
5	Vapor superheat	14.43	12.73	8.34	12.44	4.57	9.03	2.40	2.78	3.97	2.39	3.25
6	Liquid temp.	76.47	65.80	71.05	58.91	70.55	70.40	74.85	74.16	71.98	77.91	76.61
7	Liquid superheat	69.79	58.98	63.77	51.95	63.54	64.74	67.92	67.58	65.58	71.01	69.96
8	Heat of liquid	76.77	64.88	70.15	57.15	69.89	71.21	74.71	74.34	72.14	78.11	76.96
9	Latent heat at cooler pressure, B.t.u.	564.88	564.77	564.42	564.68	564.63	565.55	564.70	564.96	565.09	564.72	564.90
10	Available latent heat, B.t.u.	488.11	499.89	494.27	507.53	494.74	494.34	489.99	490.62	492.95	486.61	487.94
11	Heat of vapor, B.t.u.	7.33	6.47	4.24	6.32	2.32	4.59	1.22	1.41	2.02	1.21	1.65
12	Available B.t.u. per lb.	495.44	506.36	498.51	513.85	497.06	498.93	491.21	492.03	494.97	487.82	489.59
13	Lb. of ammonia circulated per min. from brine	20.26	20.62	20.86	15.62	24.50	28.88	20.94	20.81	21.52	15.81	26.10
14	Lb. of ammonia circulated per min. by weighing	19.01	20.00	20.20	15.78	24.80	29.87	20.76	20.43	21.04	15.6	26.00
15	Ammonia by weighing ÷ ammonia from brine, per cent	93.7	97.0	96.8	100.8	101.1	103.3	98.8	98.2	97.8	98.6	99.6

is the same in either case. When a direct-expansion plant of a cold-storage house or ice-making system is being tested similar precautions must be taken.

That the above apparatus or one similarly arranged will give exact results is demonstrated by the figures in the accompanying table. The figures of capacity given in line 1 for the eleven tests made were carefully determined and are as accurate as can be obtained when all instruments used are calibrated before and after the tests. It is the writer's opinion that the more accurate the tables of the properties of anhydrous ammonia become, the more closely will the weight of ammonia as found by actual weighing agree with the weight obtained by calculations from the heat removed in the refrigerator. The calculations given here are based on the figures in the table of the properties of anhydrous ammonia published by H. J. Macintire in the *Cold Storage and Ice Trade Journal*, August, 1912. This table while lacking confirmation as a whole, was carefully checked by the writer for ranges of pressure commonly used in connection with refrigerating plants and was found to be more accurate than the old one compiled by Wood & Davidson.

The second line in the table gives the absolute ammonia suction pressure in pounds per square inch and in the third line the corresponding temperatures of the saturated vapor in degrees Fahrenheit. The suction temperature at the cooler in line 4 shows the quality of the vapor leaving it, and it may be noticed that in all cases the suction vapor was slightly superheated. It is necessary when testing the capacity of a refrigerating plant by weighing the liquid ammonia fed into the refrigerator to so operate the latter that the ammonia vapor leaving it will be slightly superheated. This precaution must be observed to prevent liquid ammonia from leaving the refrigerator with the vapor flowing to the compressor. When the thermometer in the suction pipe to the compressor indicates that the vapor is at the temperature of saturation, the amount of liquid, if any, that it may contain cannot be determined from the temperature as the latter stays at the saturation point for any quantity of liquid present in the vapor. In the event that liquid is contained in the vapor a capacity calculation based on the pounds of ammonia fed into the refrigerator would be too high by the per cent. of liquid present to the total amount weighed.

A correction for wet vapor leaving the refrigerator can be made, but this article will deal only with the simple case where the vapor leaving the refrigerator is slightly superheated, which, by the way, is the most economical point at which a refrigerating system can be operated.

The vapor superheat and heat of vapor are found in lines 5 and 11, while in lines 6, 7, 8 and 9 the various steps to arrive at the available latent heat per pound of refrigerating medium circulated are recorded and finally in line 12 the heat absorbed by the liquid in the refrigerator for each pound evaporated is given. Dividing the values in line 12 into the heat removed from the brine in line 1 gives the weight of ammonia circulated per minute, as found from calculations based on the heat removed from the brine.

In line 14 is recorded the actual weight of liquid ammonia used per minute as determined by means of a weighing apparatus somewhat similar to the one described. In line 15 will be found the percentages that the ammonia found by weighing is more or less respectively than that determined from brine cooled. The average percentage of all the tests is 98.7 and for the ten last tests 99.2. All the results obtained by weighing, except the first one, are well within the limits of error of such experiments. The conclusion is even justified that the actual values of the pounds of ammonia circulated as found by weighing are more correct than the others. It must be remembered that by determining the actual amount of ammonia circulated by weighing, a complete record of the work done is obtained, while by recording brine readings every 10 or 15 min. any fluctuations of capacity between readings are lost sight of.

Heretofore it was deemed impossible to make accurate tests of the performance of refrigerating plants of the direct-expansion type. There does not seem to be any good reason, now that the properties of anhydrous ammonia are better known, why tests with weighing tanks should not be made and considered as, if not more, accurate than tests based on brine-cooling capacity. These tests, however, must be of sufficient length so that any error that might arise, due to the expansion side of the plant containing more or less ammonia at the end than it did at the beginning of the test, is negligible.

The actual refrigerating capacity required to make ice under varying outside temperatures, distilled water and condenser water temperatures has never been accurately determined. Allowances have always been made for radiation and other losses not directly measurable with the thermometer or with other instruments, which left the correctness of the final result very much in doubt. The question of whether or not more refrigeration is required to make can ice or plate ice, or as a matter of fact any quality of ice, can be and should be definitely settled. The most refined calculations will not equal in value a good test made with weighing tanks properly handled.

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Refrigerating Plants Installed in 1912*

New ice-making plants—under which is included additions to existing plants and the more important ice-making systems installed in connection with refrigerating plants, as at packing houses, breweries, etc.—were installed to the number of 389, as compared with 433 such installations reported in 1911.

Cold-storage houses to the number of 66 were reported (this number not including several large houses now in process of construction), as compared with 52 such warehouses, reported in 1911. The total amount of cold-storage space added during 1912, while largely a matter of estimate, is figured at over 10,000,000 cu.ft.

	Number	Tons Refr.
New ice making plants	389	17,178
Cold storage warehouses	66	3,119
Breweries	47	4,552
Packing houses	35	3,494
Provision houses	36	684
Meat markets	175	881
Creameries and dairies	169	1,948
Ice cream factories	60	1,203
Hotels	60	833
Restaurants	23	101
Produce commission houses	41	458
Oil refineries	12	924
General stores	35	243
Grocery stores	23	185
Confectioners	20	413
Hospitals and asylums	37	337
Fish freezing and storage	13	180
Office building	27	368
Schools and colleges	10	97
Residences and apartments	15	40
Miscellaneous	101	2,571
Total	1394	39,809

*From "Ice and Refrigeration," Chicago.

EDITORIALS

Engineering and the Co-operative School

At present the whole country is particularly interested in our public schools, and especially in the new coöperative high schools. The coöperative high-school courses are conducted much as are the courses in engineering advocated and practiced by Dean Schneider, of the University of Cincinnati.

In these coöperative schools the students work alternately in the classroom and the work shops of near-by establishments. A week or two is spent in the academic training in the school, and the same amount of time is allowed for practical work in the shop. This practical-theoretical training is the most common-sense method of education that high school or other boys have ever been fortunate enough to receive. The boy attending a school conducted on this plan has much to be thankful for.

From the recent impetus given to the coöperative school plan by the success of at least one such institution, it seems that educators are at last awaking to the fact that the real fundamental purpose of education is to enable us to do better the things which society through business and industry expects of us.

How it must hurt some of the old academicians to see the practical work-shop training, with grease and overalls as necessary adjuncts, supersede the "culture" of the older schools, too many of which still flourish.

To the engineer who had to struggle against the most adverse circumstances, first, for the essentials of a common school education, and second, for a training in power-plant practice, the coöperative school seems beyond reality.

The graduates of such schools will make excellent men for the power plant. Unlike some high-school graduates beginning an engineering career, they will have had most of the conceit drawn out of them by contact with actual working conditions. Most of these schools provide a training in machine-shop practice, a good knowledge of which is indeed valuable to the engineer.

The coöperative schools are sure to become more numerous. Manufacturers are glad to give their support to the plan, because boys from such schools make excellent employees.

This movement sounds a note of warning to young men who hope to become engineers, and who have not had the advantages of a good schooling. It means that they must give much time to the study of power-plant work so that they will be able to compete with their more fortunate brothers. Chief engineers can do a wonderful lot of good for young men who have not had the opportunities to get a training in the high school, or even in the higher grades of the grammar school. Mathematics and English are the subjects most needed as a basis for the education and training of such young men, and these subjects have of late been so simplified that their essentials may be mastered by diligent study. By making special provision for the training of these men in the many phases of power-plant work by making each watch engineer an instructor to the younger men as advocated by the Institute of Operating Engineers, the poor, but worthy ambitious young man will at least have a chance of competing with the more fortunate graduate of the coöperative high school.

Systematic Inspection

Only by careful and frequent inspecting and repairing can the equipment of the power plant be kept in the best condition. It is a first principle of power-plant operation that the equipment should be so maintained, but even the newest and most uptodate equipment will deteriorate rapidly if it does not receive adequate attention. Not only will the plant become inefficient and run down if it does not receive the attention that it should, but the equipment will soon become unsafe to operate.

This disease is not peculiar to the power plant alone. Every physical thing in the universe suffers change in the lapse of time. The more delicate and fine the quality of the material, the more rapidly will it disintegrate. Metal will oxidize and corrode. Wood will rot. Bearing surfaces will wear away. Parts will weaken under repeated stresses. This will occur under either static or dynamic stresses. A steel bridge is subject to deterioration just as surely as a steam engine. The power-plant owner or manager who has not taken these facts into account is the victim of his own carelessness or ignorance.

The first step in the maintenance of equipment is thorough and systematic inspection. The equipment should be thoroughly inspected at regular intervals. It is not enough to know that the boiler is washed out every two weeks. It is not enough to know that the engine is free from knocks and pounds. These are easy to attend to, but it is the elusive little things which are difficult to detect before the damage is done. Are the steam gages all correct? Are the blowoff valves tight? Are the relief valves free? Are the safety valves properly set? Are the feed-water lines free from scale and other obstructions? Are the feed pumps in proper working condition? Is the auxiliary equipment in good operating condition? All these and many more equally important facts may only be made known by careful and systematic inspection.

It is generally understood to be the duty of every operator to report any indications of trouble or cases that require attention or repair, as soon as he observes them. This is exactly the thing to do. Each operator should be trained to do this as a part of the specific performance of his duty. In addition to this it would be well to assign to one man the duty of making a careful general inspection of the plant at regular and frequent intervals. The inspector should receive assistance from the operator of the set of equipment which he is inspecting. All reasonable precautions should be taken to detect imperfect and impaired operation. Nothing should be slighted because it is out of sight or difficult of access. All in-

stances of neglect, corrosion, accumulation of dirt, lack of paint or other protection, excessive wear and incipient failure should be reported. As an aid to the process, a checking list of equipment to be inspected and irregularities to watch out for would be of value. The inspection should result in an accurate report covering the condition of the plant.

After the inspection has been made and the report completed, it should be acted upon at the earliest possible moment. If temporary repairs are necessary pending the opportunity for permanent repairs, they should be made at once. The permanent repairs should be made as soon as practicable. In power-plant operation it is not best to neglect permanent repairs simply because the equipment is still able to run. The report of such an inspection obviously is of little value unless it is acted upon promptly.

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Lubrication of Air Compressors

In the proper lubrication of the air cylinder of a compressor, probably the most important fact to bear in mind is that the oil should be used sparingly. Some operating engineers take it for granted that an air cylinder requires just as much oil as a steam cylinder and, accordingly, apply as large a quantity in the one as in the other. This assumption and procedure, however, are entirely wrong and if these engineers, or oilers, would cut down the amount of lubricant fed into the air cylinder they would be surprised at the better results they would obtain.

An excess of lubricant means not only a waste of that amount of oil, but other losses and troubles mentioned later. These losses result in a higher operating cost than necessary and, while a reduction in the aggregate cost of operating, due to a lower consumption of cylinder oil, might be very trifling where only one or two small compressors are employed, nevertheless in a fairly large station such a reduction would be noticeable. Even in a small station there is no more excuse for waste, be it deliberate or through ignorance, than in the larger one and any saving, no matter how small, will reflect to the operating man's credit.

In addition to increasing the expense for oil, excessive lubrication also results in more rapid accumulation of combustible matter on the interior surfaces of the cylinder heads as well as on the valves. Further, there is a greater tendency for the dust drawn in through the suction to adhere to the interior parts. This means more work for the operator which can largely be eliminated so that there are benefits resulting from careful attention to lubrication which may be directly enjoyed by the operator even if he is not given credit for low operating costs. In ordinary air-compressor practice and for common size cylinders, it has been found that from one to three drops of oil every five minutes will sufficiently lubricate the air cylinder. It is also a good rule to always close the lubricators immediately before the compressor is shut down.

Next in importance to proper care and attention in the lubrication of air compressors is the selection of the best suited oil. To make this selection is not always easy, as it frequently involves rather exhaustive experiments and tests and also depends largely on the amount of compression, design of compressor, etc. Careful tests of various kinds of oils should first be made to determine the flash point, viscosity and so on. In general, nothing but a high-grade mineral oil having a flash point, say above 525 deg. F., should be used. An oil containing too high a percentage of carbon should also be avoided or, in other words, an oil should be selected which will leave but very little or no carbon deposit after it is volatilized. The reasons for this are obvious. When oils are used which volatilize readily, or have a low flash point, the gases, generated by the heat of compression, pass into the discharge pipe and receivers and do not require a very high temperature to ignite. If the oil is of a coking nature it carbonizes on the air heads and valves and prevents the latter from operating properly, often resulting in some form of accident. The importance of using the most suitable oil for the purpose is, therefore, quite apparent.

The explosions that sometimes occur in air compressors are caused mainly by the ignition of combustible matter deposited on the walls of the discharge pipe and in the valve ports. As all oils contain more or less of this matter, the interior parts of the machine should be carefully inspected at certain intervals, the frequency of which will depend to some extent upon the character of the oil used. Any deposit that may have accumulated as a result of the use of oil, which has been acted upon by the high temperature of the air should be carefully removed. For this purpose ordinary soap suds may be fed into the cylinder through the regular oil cup. This application should be continued for several hours, the length of time depending upon the quantity of deposit existing. Care should be taken, however, not to let the machine lie idle with soap suds remaining in it; otherwise the parts effected will tend to rust. To avoid this possibility it is advisable to stop the feeding of soap suds a short time before shutting down the compressor and commence feeding oil.

The receiver and pipes into which the compressor discharges should be blown out regularly to remove any oil and water that might have accumulated and especially should the discharge valves be inspected and cleaned at regular intervals because if they stick they are likely to admit hot compressed air from the receiver back into the cylinder, thereby increasing the temperature of the air to such a high point before compression that it will reach the flash point of the oil during compression. It might also be added that the intake pipes should be so arranged that the free air is drawn in from the outside rather than from the engine room. This is quite important, because cold air gives a higher volumetric efficiency to the compressor, which means economy of power. Besides, it is also an effective way of decreasing the likelihood of explosions.

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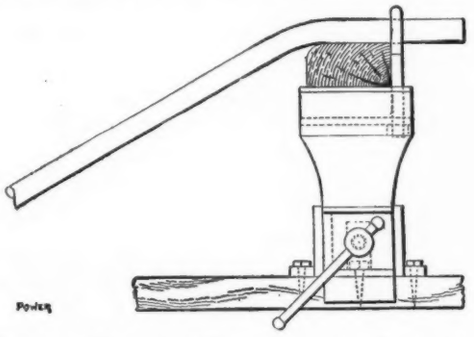
As compared with the 38 feet per second, which is considered the limit in safe speed for a cast-iron flywheel, some of the peripheral speeds attained by the disks of steam turbines are striking. In a paper entitled "Recent Developments in Curtis Steam Turbines" recently presented to the Manchester Association of Engineers, R. F. Halliwell says: "The highest peripheral speed which it is possible to employ is probably found in the 300-horsepower DeLaval turbine, in which with a 30-inch wheel running at 10,000 revolutions per minute, a velocity of over 1300 feet per second is reached.

READERS WITH SOMETHING TO SAY

An Emergency Pipe Bender

Desiring to bend a piece of ¾-in. conduit, and not finding anything suitable with which to bend it, I took an ordinary ½-in. eye-bolt, screwed a nut on it and clamped it in the vise as shown in the illustration. Then rounding one side of a wooden block to be used as a fulcrum, I found that bends and offsets could be easily formed.



PIPE BENDER MADE OF EYE-BOLT AND BLOCK OF WOOD

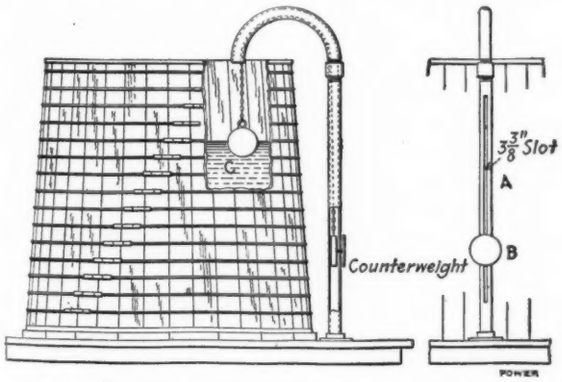
This bender could doubtless be improved upon, but it does exceptionally well in an emergency. As the fulcrum is made of wood, it does not kink the pipe as does an ordinary bender, or, what is commonly called, a "hicky." The wood block should be made of oak or maple.

GROVER M. HARDY.

Selina, Kan.

Water Level Indicator

The illustration shows an indicator used to show the height of water in tanks on top of buildings. We have tried several designs of water-level indicators and found that while they worked well in summer they gave trouble



WATER-LEVEL INDICATOR FOR ROOF TANK

in winter, due to water freezing on the chain connecting the float with the indicator hand. As ice would accumulate on this chain it would not allow the indicator to register the proper water level. The indicator shown is made of 2-in. pipe in the form of a return bend of about 2-ft. radius. A slot *A* is cut in the straight pipe, and in it a pin carrying the tin plate *B* slides, with the rising or falling of the water level. This tin plate is connected with a chain that runs inside the pipe, and at the tank end is connected with the float *C*.

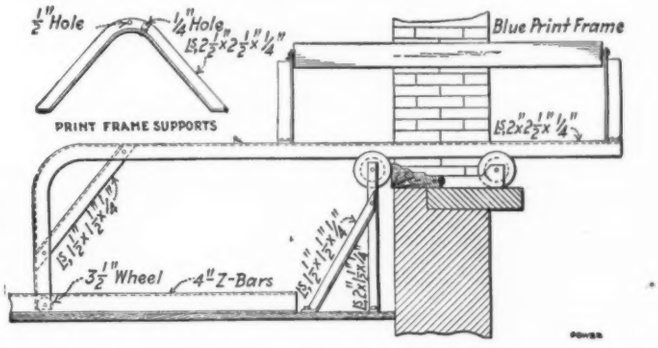
This indicator works well, as very little ice accumulates on the chain, and such as there is, does not interfere with the operation of the indicator; in fact, it makes it work better, as the ice offers less resistance to the travel of the chain through the pipe than does the bare chain.

HARRY BIEHL.

Philadelphia, Penn.

Disappearing Blueprint Frame and Carriage

At times, to secure a proper amount of sunlight, it is desirable, or perhaps even necessary, to place a blueprint frame on the front or side of a prominent building. In such cases the usual type of carriage running on a fixed track supported by brackets fastened to the outside of the building is objectionable because it is unsightly. A disappearing track and carriage showing only while in service is required. The one shown herewith has been in use several years and has proved very satisfactory.



SHOWING CONSTRUCTION OF DISAPPEARING BLUEPRINT FRAME AND CARRIAGE

The method of construction and operation is readily apparent. The frame, large enough to take tracings 36x 48 in., is mounted on a carriage made of angle iron and arranged to move in and out of a window on groove wheels held loosely on a ½-in. axle.

The wheels on the window ledge are set out as far as possible from the ledge, being held in place by brackets fastened to the window sill. The Z-bars should be long enough to serve as girders for the rear of the carriage when it is being drawn in; they also prevent the carriage from tipping up when pushed out. To allow the frame to be turned in any position directly toward the sun it is pivoted on ½-in. pins, one at each end. At one end a second pin, ¼ in. in diameter and 3 in. from the pivot pin, is arranged to slide into holes in a brass plate on the frame, thus holding it rigidly in any desired

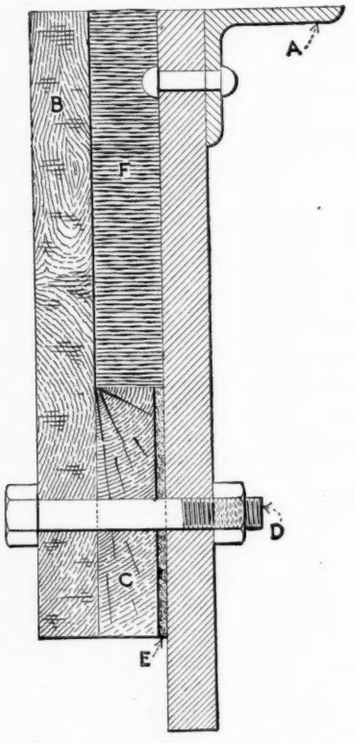
position. Unless the height from the window sill to the floor is unusually low a platform will be needed to stand on to conveniently reach the frame so that prints can be easily put in and taken out.

F. G. HECHLER.

Troy, New York.

Stopping Leak in Submerged Tank

The accompanying sketch illustrates the manner in which a temporary repair was made to a submerged condenser tank, where the sides of the tank riveted to the angle iron *A* had rusted badly, allowing a number of rivets to be pulled out. In the illustration, *B* is a ½x6-in. yellow pine board; *C* is a ½x3-in. yellow pine piece, and *D* is a ⅜-in. bolt. Five of these were placed at 18-



BOARDS, PITCH AND FEFT ON SIDE OF TANK TO STOP LEAK

in. centers around the tank. About 6 in. below the top of the tank is a piece of folded felt *E* thoroughly painted with asphalt. At *F* is shown pitch which was poured in while hot. An inexpensive repair of this kind prolongs the life of a tank for a year or so until the deterioration of other parts justifies the installation of a new tank.

G. A. ROBERTSON.

Louisville, Ky.

Compression vs. Cylinder Condensation

The experiments of Prof. Dwelshauvers-Dery, where he practically and definitely demonstrated that an early closing of the exhaust valve in a steam engine, causing compression before admission, is an uneconomical way of heating the cylinder walls, seemed to be contradicated by the tests of the performance of the Uniflow engine, in which high compression is a salient feature, indirectly productive of economical results. The contradiction, though apparent, is not real, and compression is not economical, but an early closing of an exhaust valve will not only cause compression, but will also prevent or reduce reëvaporation of the liquid during the exhaust stroke; and will thereby reduce the initial condensation due to contact with the cylinder walls cooled by reëvaporation during exhaust.

It might perhaps be claimed that by closing the exhaust valve before all the moisture has been removed, the cylinder will accumulate too much liquid, detrimental to the proper action of the working fluid (steam under pressure), but it must be remembered that the liquid removed by reëvaporation on the cylinder walls, is again replaced by initial condensation of live steam. As the latent heat of steam at high pressure amounts to less heat per pound than the latent heat required for vaporization of liquid at exhaust pressure, prevention of reëvaporation during the exhaust might even reduce the average moisture. A pound of water evaporated at 212 deg. will remove 970.4 B.t.u. from the cylinder walls, while the latent heat that a pound of steam at 115 lb. absolute can furnish is only about 880 B.t.u.

The loss due to reëvaporation during exhaust is greatest when the steam contains moisture at the throttle, because a pound of moisture or liquid at 115 lb. absolute contains only about 129 B.t.u. above the heat of the water at 212 deg., and that pound of moisture, if reëvaporated during exhaust, will carry away 970.4 B.t.u., a loss of

$$970.4 - 129 = 841.4 \ B.t.u.$$

Any such loss, to be made up by live steam entering at 115 lb. pressure with 1010 B.t.u. per lb. above the heat of the liquid at 212 deg. and leaving as steam through the exhaust with 970.4 B.t.u. per lb., will be made up at the rate of

$$1010 - 970.4 = 39.6 \ B.t.u.$$

per pound condensed.

A pound of moisture reëvaporated on the cylinder walls during exhaust will cause the condensation of

$$841.4 \div 39.6 = 21.25 \ lb.$$

of steam at 115 lb. pressure. This is a good reason for using a separator at the throttle so that the steam enters the cylinder as dry as possible.

If heat transmission was instantaneous the cylinder walls would be alternately as hot as live steam and as cold as exhaust, and the limits to cylinder condensation and reëvaporation would be set by the specific heat of the metal times the weight of the metal affected. However, all the liquid cannot be reëvaporated during the exhaust. It takes time to transmit heat, and the time depends on the conductivity of the metal and the fluid, the amount of surface affected, the amount of the difference in temperature, the amount of moisture in the steam and the nature of the agitation.

In compound engines the reduced range of temperature decreases heat transmission.

In Uniflow engines the reëvaporation of moisture during exhaust is almost entirely prevented, and the cylinder walls are so warm that but little condensation takes place.

In any engine, if the time of reëvaporation during exhaust is reduced, as by compression, the initial condensation is also reduced. Furthermore, when a piston has reached the greatest velocity in the stroke, and its motion is retarded as the crank gets near the center, the

moisture swept by the piston is thrown against the cylinder head, causing an agitative effect and increased facility for reëvaporation. If the exhaust valve then is closed, so that the agitation takes place under an increasing pressure there is no more reëvaporation during that stroke.

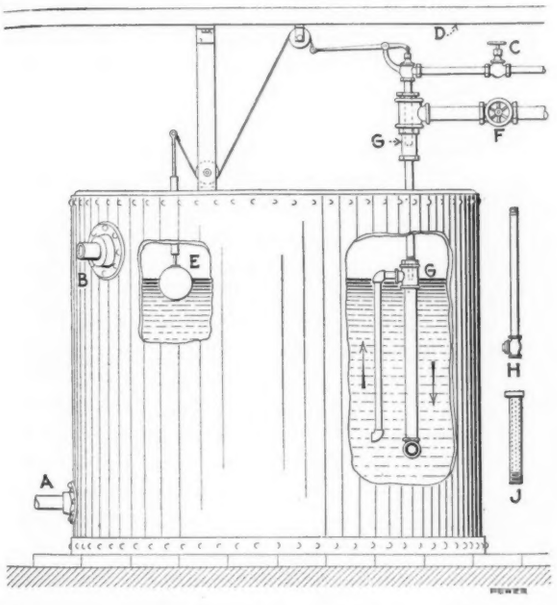
Superheat, compounding, steam jackets, etc., are means employed to prevent or reduce cylinder condensation, and permit the steam to expand as nearly as possible like a perfect gas. If there was no reëvaporation during exhaust, the cylinder condensation would only be enough to make up for heat lost externally by the cylinder, heads, rod, etc.; but reëvaporation during exhaust increases cylinder condensation to such an extent that it can be economical to use compression as a remedy.

C. Osborne.

New York City.

Serious Water Hammer in Feed-water Tank

We had a 1000-gal. tank made, in which to collect the condensation from the heating system and other sources, and to supply the boiler-feed pump through the pipe *A*. A pipe leads from the flange *B* to the atmosphere and contains no valve. Cold water is supplied through valve *C* and the valve *D*, the water level being regulated by the float *E*. Exhaust steam is supplied through the valve *F* at about 2 lb. pressure, and according to theory should



Connections to Feed-water Heater to Prevent Water-hammer

form a siphon condenser in the mixing chambers *GG* and incidentally the water should circulate in the pipe as shown by the arrows.

So much for theory; but this is what happened when the steam was turned on: Severe water-hammer was set up in the heater, which sounded like the blows of a heavy sledge hammer, and, notwithstanding that the heater was open to the atmosphere, this heavy tank jumped and danced away from its place on the brick floor, the vibrations being transmitted throughout the building.

The trouble was remedied entirely by embedding the tank in 3 ft. of concrete as a foundation, and by screwing the pipe *H* with a check valve attached, into one of the elbows, in the up-pipe shown by the arrow, and attaching the capped perforated pipe *J* to the other pipe. This stopped all vibration and only a very slight rumbling is occasionally heard.

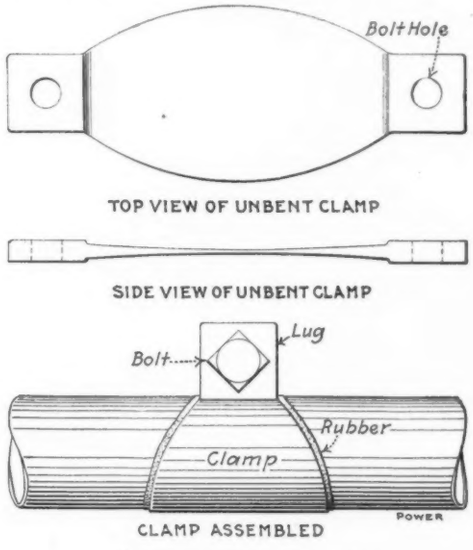
Charles Haeusser.

Albany, N. Y.

Pipe Clamp for Leaky Pipes

A simple device by which a leak in any size water, steam or gas pipe may be temporarily repaired is shown in the accompanying illustrations. It can be made by a blacksmith at a slight cost by ordering several of one size at a time.

This device is of wrought iron and for pipe under 2½ in. should be slightly less than $\frac{1}{16}$ in. thick at the bottom,



Homemade Pipe Clamp

so as to be somewhat flexible, and gradually increasing to ⅛ in. in thickness at the base of the projections or lugs, at the top. The latter should be about ¼ in. thick, have a height and width of 1 in., also a hole in the center of each lug to take a ⅜-in. bolt, to fasten the clamp to the pipe. The greatest width of the clamp should be at the extreme bottom and about 1¾ times the nominal diameter of the pipe for which it is made. The clamp should be made so it will be in contact with the pipe through an arc of about 300 deg.

When using this device a piece of cloth insertion rubber, at least $\frac{1}{16}$ in. thick and a little larger than the clamp should be placed over the leak in the pipe, and the clamp placed over it. A ⅜-in. bolt is put through the holes in the lugs, and after placing a washer and nut on it, is tightened up.

I have used this clamp successfully in repairing leaks in piping that were almost inaccessible, and where, if the lengths had been removed, a considerable loss of time, labor and money would have resulted. This device can be applied without reducing the pressure on the system.

E. Oster.

Cincinnati, Ohio.

QUESTIONS BEFORE THE HOUSE

Acid in Oil May Cause Corrosion

In the Nov. 26 issue, H. K. Wilson speaks of trouble with a crosshead caused by corrosion of the threads. I believe this trouble to be caused by sulphuric acid in the engine oil. This acid is used in treating oil in some processes and should be neutralized, but sometimes this is not done.

The acid remains inert as long as no water is present, but on coming in contact with moisture from the stuffing-box leakage it becomes active, corroding the iron. A simple test for sulphuric acid is to make a saturated solution of barium chloride in distilled water. Take about an ounce of the oil, and dilute it with an equal quantity of benzine or gasoline to make the oil more limpid and add a few drops of the barium solution.

If sulphuric acid is present a white precipitate will form and if it does so the oil should not be used where it will come in contact with moisture. Some years ago I had trouble with a pair of wristpin boxes from the same cause, and they were nearly ruined before I found and removed the cause of the trouble.

C. A. GREEN.

Cleveland Ohio.

Rising Tide Fills Receiver

The letter by Mr. Adams, under the above caption, page 614 of the Oct. 22 issue, shows the necessity of carefully studying the piping and equipment in power plants. Frequently engineers taking charge of new or strange plants find many little faults in the piping which have been overlooked by the steamfitters, and, if left as found, would conduce to damage to the equipment.

Relative to the plant mentioned by Mr. Adams, a check valve should have been placed in the drain pipe above the funnel; this would have prevented the water from being drawn back into the receiver. Most compound engines have a steam trap connected to the receiver, and a check valve between the receiver and the drain pipe. Then only the condensate from the steam as it is passed through the piping and receiver can accumulate in the receiver while the tide is high.

In a plant in this locality some years ago, the cylinder heads of three engines were blown off as the engines were being started for the day's run. This plant was run noncondensing. The exhaust line ran along under the floor, through the engine room to the boiler room, which was 70 or 80 ft. distant, where it was then connected into an open feed-water heater. The exhaust main had gradually filled with water during the night, because the float valve which controlled the city water supply to the heater became inoperative and allowed the full city pressure to flow into the heater, the overflow not being able to pass out all the water, allowed it to rise high enough in the heater to flood the exhaust line. This exhaust line was trapped, but the trap could not take care of the extra water, and so the pipe became full during the night.

These conditions were not known to the engineer who started one of the engines, which made but a revolution or two, when the entrapped water in the cylinder, being compressed by the piston, blew off the low-pressure cylinder head. Thinking that this water was due to condensation in the steam-supply pipe, he immediately started one of the other engines and the same thing happened to this one. By this time he was so thoroughly excited, and as it was after the usual starting time, he jumped to the throttle of the third engine and, opening it, caused the cylinder head to be blown out as it had been on the other two. The real cause of the trouble was discovered, as usual, when it was too late to do any good.

R. A. CULTRA.

Cambridge, Mass.

Measuring Air from Compressor

As a rough and ready method, Prof. Fessenden's suggestions in the Dec. 31 issue seem good, but I disagree with his assertion that his method can be made very accurate, and I take the liberty of questioning both its practical and theoretical correctness. In the course of the article he says that "the volume and temperature remain constant and the pressure and weight decrease as the air escapes through the partly open valve *B*." The very first principle of air compression and expansion is that the temperature will change with the pressure. The test proceedure is to expand the air in the tank from a pressure 10 or 15 lb. above normal, down to some pressure below normal, then plot a curve of pressure drop with time, from which the tangent angle will give the first differential, or rate of flow. It seems to me that this assumes the expansion to follow the equation, $W = PV \div RT$, which he has given, assuming, as he says, that the temperature shall remain constant. A single trial will convince anyone that the temperature in the tank will not remain constant. I have in midsummer formed good-sized chunks of ice, which come shooting out of a receiver drain, by allowing the air in the receiver to expand down from 100-lb. gage to atmosphere. There is little or no cooling of the air after passing the orifice, but if the body of air in the receiver is allowed to expand that way, the expanding air in the receiver will grow intensely cold and will carry out chunks of frozen moisture.

When the pressure is increased to 10 or 15 lb. above normal, the air gets hotter because the compression range is increased; but not very much hotter, as regards the entire body of air in the receiver, because the new, more highly heated air is a very small proportion of the tank contents. Now, however, when the entire tankful is allowed to expand back to normal pressure, there is a very rapid temperature drop, and when normal pressure is reached again, the temperature will be much below normal. Thus the condition of flow at normal pressure may be entirely different from what it was at first.

It is true that the volume flowing from an orifice varies only with the square root of the absolute temperature, so if the original pressure increase is but slight, it may be that the curve of expansion will be true enough at the point of normal pressure to give a rough approximation to the flow rate. That it is theoretically correct, as claimed, I doubt very much.

A little further along he says that the thermometer must be "carefully calibrated, and that the temperature of the air should remain the same when the readings for the pressure-time curve are taken as when valve *B* is adjusted." To carefully calibrate a thermometer is easy, but as to the last injunction; how does he do it? I have seen the mercury skip up and down in a thermometer at a lively rate as air was compressed and expanded in a receiver. This naturally brings up the question; if expansion of the air in the receiver lowers its temperature, why will it not be equally raised by pumping more air into the tank, and so raise the pressure?

Some reader will say, "it does." But try this: Have an air receiver connected to the shop air line, but with the air valve closed and the pressure in the receiver at atmosphere. Now open the valve to admit air from the shop line, all outlets from the receiver being closed. If the shop line air is cold, as it usually is, will the receiver become hot when the pressure within it is raised to, say 100 lb., with the cold shop line air? Any increase in the heat in the air would mean an increase of energy in the air, and there is no place for this energy to have come from. It could not come from the compressor, as this reasoning will prove: Suppose the compressor to be running at constant speed and blowing off all its capacity at full pressure to atmosphere from a bypass. Further, assume for ease of reasoning that, by the time the air has reached the blowoff, it has cooled down to atmospheric temperature in the shop line, as it usually does. Now, the compressor is developing a certain horsepower, delivering a certain amount of air at, say 100-lb. pressure, 60 deg. F. Suddenly close the blowoff and open the valve into the receiver, filling the latter with the cold air, but throttling the flow so as to maintain the compressor discharge pressure at exactly 100 lb. until the receiver is full.

During this process the conditions at the compressor must have remained constant. If it was delivering cold air to the blowoff, it must deliver cold air to the receiver and the latter is then filled with cold air. The air in the receiver cannot increase in temperature, because if it did it would contain more energy than it had when passing out of the blowoff, and it cannot contain more energy because the compressor horsepower has very clearly remained constant. The air passing from the line pipe into the receiver may grow a shade colder, but only a shade, because the pressure in the air line has not been allowed to drop.

If, however, the shop line is closed off and the air in the receiver allowed to blow down to atmosphere, pieces of ice will shoot out of the receiver blowoff when the receiver pressure has gotten down to about 10 lb.

I have never noticed any increase in temperature in filling a tank with air at normal temperature from the 100-lb. shop line. I have, however, often noticed marked increase in temperature in a receiver filled with air and then further compressed in the receiver by pumping water into the bottom, thus decreasing the air volume and increasing the pressure. Increase of pressure by decrease of volume will increase air temperature; but increase of pressure by crowding in more air at normal temperature does not appear to increase the temperature, nor does a consideration of the energy transfers lead to such a conclusion. Expansion of air through an orifice, or valve, as in opening a cock on an air line, will scarcely decrease the temperature of the escaped air at all; but expansion of a body of air from one pressure to another, as in blowing down an air receiver, so that the pressure within the receiver is decreased, will rapidly decrease the temperature of the air within the receiver.

R. S. BAYARD.

New York City.

Explosions in Air Lines

The article by Frank Richards, of July 30, 1912, issue of POWER, has brought forth considerable discussion in regard to dangerous explosions in receivers of compressed-air systems. It seems to be the consensus of opinion that these explosions, sometimes fatal, result from an abnormal increase in temperature, which is sufficient to vaporize the grease which lines the discharge pipe and receiver, thus supplying a mixture of oil and air which explodes when the temperature rises sufficiently. No cause, however, for this rise in temperature is offered.

It is only natural that the result of the explosion should appear in the receiver since the receiver is the weakest part of the system on account of its large size and comparatively thin shell. Anyone who is seriously interested in this subject might very profitably look up the details of the explosion of a four-stage air compressor at the Redstone plant of the H. C. Frick Coke Co., Brownfield, Penn. To guard against the repetition of a former violent explosion, a recording thermometer had been installed in the pipe line for the outgoing air close to the compressor. Fusible plugs were also attached to the discharge pipe as a further safeguard.

When the compressor was working normally, day in and day out, the temperature of the discharged air was ordinarily about 240 deg. F. and practically never more than 250 deg. F. On the day of the explosion, the temperature for the first part of the morning was the same as usual, but at 11 a.m. the temperature started to increase and reached about 270 deg. F., indicating trouble. The temperature remained at approximately this point for 3½ hr. so that there was plenty of time for the engineer in charge to discover the unusual condition and to shut down the compressor for investigation. Apparently the engineer took a long chance and as a result an internal explosion took place at three o'clock in the afternoon. The chart record shows that the temperature rose to 620 deg. F. almost instantaneously, being checked here by the blowing out of a fusible plug.

The cause of the rise in temperature in air compressor lines has been given careful consideration by engineers of large coal companies using compressed air for power purposes. It is generally believed that the high temperatures are a result of the continued recompressing of air in the compressor cylinder, due to improper action of the air valves. Heat is generated when air is compressed and if the valves do not prevent this heated air from getting back into the cylinder to be compressed again, the air will become hotter and hotter, depending on the efficiency of

the water-cooling system, until finally the temperature will reach a point where the lubricating oil and the grease lining the discharge pipe and receiver will become vaporized and finally ignite, resulting in an explosion.

Normal working temperatures of air leaving compressors vary somewhat according to the compressor and the efficiency of the cooling system. Blowing engines, such as are used for blast furnaces and for bessemer converters, compress the air to about 10 to 30 lb. per sq.in. Neither the air cylinder nor the discharged air are water-cooled and the temperature of the air in the blast main will usually remain at about 300 deg. F. under proper conditions. The blast main becomes lined with grease, the same as the discharge pipe for high-pressure air but, as the air is at a fairly low pressure, a fire results instead of the explosion in high-pressure lines. These fires are a result of the same trouble, improper working of the valves. In the case of blowing engines, however, the fires take place within the time of about three or four revolutions of the engine after the valve trouble occurs, because no cooling water is used. The effect of water cooling in air compressors prevents an instantaneous explosion when the valves are not working properly, thus allowing sufficient time to shut down and investigate. As previously stated, the temperature of the discharged air will largely depend on the amount of cooling applied. The air from the four-stage compressor at Brownfield, Penn., was normal at 220 to 250 deg. F. Records from three-stage air compressors in the same district show normal temperatures of 275 to 310 deg. F. A single-stage compressor would likely discharge air at something under 300 deg. F. with normal conditions, and this is safely below the ignition point of good lubricating oil.

To prevent these disastrous explosions, very nearly all of the coal operators using multiple-stage air compressors in the western Pennsylvania district have equipped their compressors with recording thermometers so that the engineer in charge will have complete information of the temperature of the discharged air and so that there will be records of these temperatures for the superintendent. One of the large coke companies has also devised an automatic electrical emergency shutdown device which is operated from the thermometers. Another method, which is less expensive, consists of having a gong sounded when the temperature rises sufficiently to close electric contact in the thermometer, thus giving warning to the engineer that the compressor is not working properly.

The suggestion of Thomas Baker, in POWER for Dec. 31, 1912, is good, that "Only the very best grade of air-compressor oil obtainable for lubricating the cylinders be used." It is quite likely also that the amount of oil for the compressors could be considerably reduced.

Pittsburgh, Penn. R. B. ANTHONY.

World Beating Discoveries

Many such wonders as are referred to editorially under the above heading, in the Dec. 3 issue, have a basis of truth, but fail because they are out of proportion.

Take, as an example, the proposed production of liquid carbon dioxide from furnace gases by methods which involve centrifugal separation. Consider this idea in the light of the kinetic theory of gases. This theory postulates a gas as made up of innumerable small particles, endowed by heat with mobile power and darting to and fro at enormous velocities. The particles possess weight, and are therefore subject to the attraction of gravity.

It can be shown that the atmosphere about the earth exists, where it is as a compromise between gravitation and molecular velocity. This being true it should be possible, in a closed vessel of mixed gases, well insulated from changes of temperature which would cause currents and induce mixing, to show a greater percentage of the heavier gases, collected by settling at the bottom of the vessel. It should also be possible by producing a whirling movement in any smooth container, so far to increase the different gravitational influence on molecules of different weights as to cause the heavier ones to be separated toward the outer part of the vortex. But the added energy would be so small a part of the total molecular energy that the practical effect would be little.

If two gases be separately imprisoned in a vessel with a central sliding door between them, then when the door is removed, those molecules which were by the door will begin to diffuse into the next compartment. This power of diffusion varies inversely as the square root of the density of a gas. Thus if the two gases are oxygen and hydrogen the densities of which are 16 and 1, their diffusive energy will be as 1 to 4, and the first molecules of hydrogen will penetrate 4 ft. into the mass of oxygen in the same time as occupied by the molecules of oxygen in penetrating only 1 ft. into the mass of hydrogen. This diffusion runs counter to other influences and enables oxygen to find its way to the floor of a mine in spite of the superior gravitational pull upon the carbon dioxide. Thus diffusion and temperature-produced currents mix up the atmosphere preventing gravitational stratification.

Since 14 cu.ft. of air weighs one pound and the atmosphere weighs upon each square inch about 15 lb. the height of the atmosphere, were it uniformly dense vertically, would be about 28,000 ft. And since its content of carbon dioxide is one in 10,000, this gas would cover the earth's surface to the depth of nearly three feet. No small animal could live at the sea level.

That we owe mixture to diffusion can be shown by removing the heat which gives to gas molecules this energy of motion. Gases liquify at different pressures and temperatures, and air can be separated into its constituents by compression at a very low temperature, the more easily liquified gases being drained off before the less easily liquified gases lose their gaseous state. The reverse effect, or distillation, has long been employed to separate mixed solids and liquids.

At a velocity of 1920 ft. per sec., a gas molecule, starting upward from the earth would ascend for

$$1920 \div 32 = 60 \; sec.$$

In that time it would reach a height of $16t^2$ ft., or

$$3600 \times 16 = 57{,}600 \; ft.$$

or 11 miles, which would be the depth of the atmosphere for a gas of that molecular velocity. The moon possesses little or no gas because its gravitation is insufficient to restrain the molecular energy with which gaseous molecules travel from it. With such a view of molecular gaseous energy it is obvious that gases cannot be much influenced by such movements as can be mechanically impressed upon them and would-be revolutionaries in the engineering world would do well first to acquire a knowledge of some of the basic laws against which they may be running counter.

London, England. W. H. BOOTH.

INQUIRIES OF GENERAL INTEREST

Water Temperature in an Open Heater—Why cannot water be raised above a temperature of 212 deg. in an open heater?

K. F. N.

Because, in an open heater the water is under atmospheric pressure, and its highest attainable temperature is 212 deg. F.; above, that temperature it becomes steam under atmospheric pressure.

Motor Windings—What is the difference in the effect of a differential and of a cumulative winding upon the speed of a motor?

C. F. N.

The effect of the differential winding is to increase the speed as the load increases, whereas that of the cumulative winding is to increase the speed as the load decreases.

Reversing Motor—How may a shunt-wound motor be reversed?

H. F. C.

By interchanging the field connections or the line connections at the brushes, or, in a bipolar machine, by shifting the brushes 180 deg.; in a four-pole machine, 90 deg.; in an eight-pole, 45 deg., etc.

Fire Crack on Boiler—What causes a fire crack on a boiler; where do they most often appear and are they dangerous?

G. N.

A fire crack, as distinguished from a rupture due to a strain, is caused by the action of the furnace heat. These cracks sometimes occur in the body of a boiler sheet or along its edge, and occasionally in the rivet head or between the rivets. Usually the crack begins at the fire surface. It is dangerous only when the crack increases in depth, thereby impairing the strength of the material.

Evaporation in Draft Gage—How can evaporation in the draft gage be prevented?

J. S. H.

A good way is to place about one-half inch of a light oil on the surface of the water in each leg of the U-tube, being careful that there is the same amount of oil in each. Then the difference between the level in the two legs may be read off, giving the draft in inches of water the same as though no oil was used. Covering the surface with oil prevents evaporation of the water, but care should be taken that when the draft gage is disconnected in the open atmosphere the water level stands the same in each leg of the U-tube.

CO_2, CO and H_2O—What is meant by CO_2, CO and H_2O?

J. P. M.

CO_2 is the chemical symbol for carbonic acid gas and means that in each molecule of the gas there are one atom of carbon and two atoms of oxygen. CO is the symbol for carbonous acid gas, each molecule of which is formed of one atom of carbon and one atom of oxygen. This gas is the result of incomplete combustion, for CO can still burn to CO_2. Consequently, when CO is the product of combustion, not so much heat results from a given quantity of fuel as when the product is CO_2. H_2O is the symbol for water and water vapor, each molecule of which is the combination of two atoms of hydrogen and one of oxygen.

Position of Gage-Cocks—Why are the gage-cocks ranged in a slanting line in the boiler head?

J. E. R.

If the holes in the head were in a vertical line, bringing one cock plumb above or below another, the cocks would come so close together for indicating the desired differences of water level as to leave too small a ligament of metal between the holes made in the head to receive the gage-cock connections. Hence the line is slanted from the vertical. Another reason for slanting the line of cocks is to prevent the discharge of one cock from falling on another, and also to leave sufficient space between the cocks for fitting them up and for operating them.

Coal Consumption—Is 14¼ lb. of buckwheat coal per square foot of grate area a fair average of coal consumption for a water-tube boiler with a steam blower discharging under the grate?

G. E.

Burning 14 to 19 lb. of buckwheat coal per square foot of grate would be only a fair average with natural draft. With forced draft it should be possible to burn as high as 25 to 35 lb. per square foot of grate with good results. In using forced draft it is assumed that only as much boiler capacity is employed as may be necessary. With insufficient natural draft and where forced draft is necessary, it is better to force the boilers beyond their rated capacity and employ only as many boilers as may be necessary.

Thickness of Boiler Heads—Is there a formula or rule for finding the thickness of boiler heads for a given thickness of plate? For example, should a boiler with ½-in. plates and over have ½-in. heads?

E. W. H.

The thickness of boiler heads of return tubular boilers is not determined by a mathematical calculation but empirically from practice. The Massachusetts rule requires that boilers 42 in. in diameter or under shall have heads ⅜-in. thick; from 42 to 54 in. diameter, inclusive, $\frac{7}{16}$-in. heads; 54 to 72 in. diameter, inclusive, ½-in. heads and over 72 in. diameter, $\frac{9}{16}$-in. heads.

Sampling Coal—How should a sample of coal be selected for a proximate analysis?

C. A. H.

Sampling may be done according to the A. S. M. E. Code for Conducting Boiler Trials, the rules for which may be found in various text and hand books. A simple method that will give very close results is as follows: Select equal samples from various parts of the coal pile. Thoroughly mix and crush them, then halve the quantity, quarter it, and so on, repeatedly divide it, until only as much remains as is required for the analysis. It is well to repeat the mixing frequently and also the crushing if the coal was not originally pretty finely powdered.

Pumping Pressure—Against what pressure can water be forced by a pump having 7-in. water and 5-in. steam cylinders, taking steam at 80 lb. pressure?

K. F. N.

Theoretically, the pressures in the two cylinders will be inversely as their areas, and the latter are proportional to the squares of the diameters. Then the pressure in the water cylinder would be

$$\frac{25 \times 80}{49} = 40.8 \text{ lb.}$$

Practically, on account of friction, and the actual mean effective pressure being less than the initial pressure, even with steam supposed to be taken during the full stroke, at least 10 per cent. less pressure would be all that could be pumped against or around 35 lb.

Proximate Analysis—What is the proximate analysis of coal and how is it obtained?

H. A. C.

What is known as the proximate analysis of a fuel is one which determines the relative proportions in the fuel of fixed carbon, volatile matter, moisture and ash. Progressive heating separates these parts and weighing the remainder at each stage enables computing the various percentages. At a temperature of 250 to 300 deg. F., all the moisture will be driven off. Further heating to a red heat will remove the volatile matter, and at a white heat the carbon will unite with oxygen to form CO_2, leaving the ash as the final residue.

The principal apparatus required for ordinary boiler room use includes a crucible about 6 in. in diameter, a cover for the crucible and sensitive scales, such as are used by druggists. For the heating, the most available means will answer, as the boiler furnace itself. The crucible may be held in the furnace with tongs or on an old shovel. For the first heating, to drive off the moisture, the crucible may be set just inside the fire door on the dead plate. A blacksmith's forge or a large enough Bunsen burner may also be used for the whole range of heating. To begin with, the empty weight of the crucible must be taken so that it may be deducted from the final weight to get the weight of ash.

ENGINEERS' STUDY COURSE

Mensuration—Part I

Mensuration is really "short-hand" geometry, because it treats of the measurements of lines, angles, surfaces and solids, while geometry is the science which proposes and demonstrates the art of measuring. Mensuration is especially valuable to the engineer, for by knowing how to use it he can measure the volume of tanks and vessels of all shapes, the area of surfaces, regular or irregular.

Lines and Angles

A *geometrical* line has length but not breadth nor thickness. Lines may be straight or curved.

A *straight line* is one that does not change in direction throughout its length, as the line *AF* in Fig. 1, or the lines *AE, BF, CG* and *DH* in Fig. 2.

A *curved line* changes in direction at every point. Straight lines are designated by two letters, while curved lines are usually designated by three letters. The lines *ACE, CEG, EGA,* which describe the circle in Fig. 2, are curved lines.

Parallel lines are lines which are the same distance apart throughout their entire length, as the edges of the top and bottom crosshead guides of an engine.

A line is *perpendicular* to another when it meets the other line at right angles. Thus the line *CO,* Fig. 2, is perpendicular to the line *AE.*

A *vertical line* is a line pointing toward the center of the earth, such as a plumb line, or line holding a suspended plumb-bob.

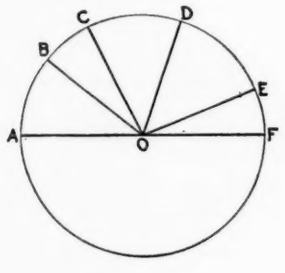


Fig. 1

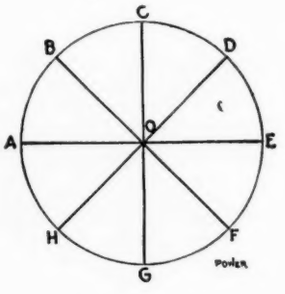


Fig. 2

An *angle* is the difference in direction of two intersecting straight lines which may be considered as running from the center to the circumference of a circle. Thus the lines *AO* and *BO, CO* and *DO,* Fig. 1, form angles.

The *vertex* of an angle is the point where the lines forming the angle meet. As seen in Fig. 1, *O* is the vertex of all the angles.

To understand the angle we must understand the circle. The circumference of the circle is considered as being divided into 360 equal parts, each called a *degree.* A degree is divided into 60 equal parts, each of which is termed a *minute.* The minute in turn is divided into 60 equal parts, each of which is termed a *second.* From this we see that the length of a degree, minute or second measured on the circumference will vary for different-sized circles, but that *a degree of any circle is equal to* $\frac{1}{360}$ *of its circumference.* The degree, minute and second are expressed, °, ′, ″ respectively. Thus for the expression, 20° 16′ 50″, we read 20 degrees, 16 minutes, 50 seconds.

Any circle contains four right angles. Then a right angle must be equal to $\frac{360}{4} = 90$ deg. Thus in Fig. 2 *COE, EOG, GOA* and *AOC* are right angles, or 90-degree angles. A 45-degree angle must be $\frac{90}{2}$, thus *AOB, COD, DOE,* etc., in Fig. 2, are 45-degree angles.

An *obtuse angle* is any angle greater than a right angle. Thus the angle *BOE,* Fig. 2, is an obtuse angle. An *acute angle* is any angle less than a right angle; as the angle *DOE,* Fig. 2.

When a straight line, as *BO,* Fig. 2, meets another line, *AE,* between its ends, two angles, *BOA* and *BOE,* are formed. Angles formed in this manner are termed *adjacent angles.*

From the foregoing we see that no matter how many lines we draw through the center of a line, such as *AE,* Fig. 2, or how many lines we cause to meet at a point *O* on a line *AF,* Fig. 1, the sum of all the angles formed cannot be more than four right angles in the case of Fig. 2, nor more than two right angles in the case of Fig. 1. Then if we are told how many lines, spaced equally, are drawn through the center of a circle, we can easily find how many degrees there are in the angle included between any two of these lines. Thus suppose there are eight lines, as in the case of the center line of the arms of an 8-arm flywheel. Then the angle made by any two adjacent arms is $\frac{360}{8} = 45$ deg.

The Circle

As we all know, the circle is a figure bounded by a curved line, termed its circumference, every point of which is equally distant from a point called the center.

An *arc* of a circle is any part of its circumference, as *ABC,* Fig. 3. If we know how many degrees there are in an arc we know directly what angle will be formed by lines drawn from its extremes or ends to the center of the circle which it represents. Conversely, if two lines drawn from the center to the circumference form an angle of a given number of degrees they will meet the circumference at the ends of an arc of the same number of degrees.

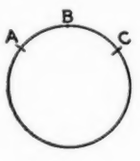


Fig. 3

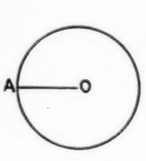


Fig. 4

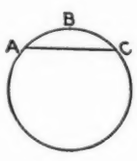


Fig. 5

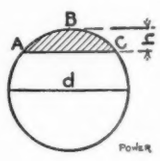


Fig. 6

The *radius* of a circle is a straight line drawn from the center to the circumference, as the line *OA,* Fig. 4. When this line extends all the way across the circle, as at *D,* Fig. 6, it is called a diameter.

A *chord* of a circle is a straight line joining any two points on the circumference, as the line *AC*, joining the ends of the arc *ABC*, Fig. 5.

A *segment* of a circle is the area included between a chord and the arc, as the shaded part in Fig. 6. The height of a segment of a circle is the distance *h*, Fig. 6. A segment may be less, equal to, or greater than a semicircle (half circle).

A *sector* of a circle is a part of a circle shaped like a piece of pie. Referring to Fig. 2, the area included between the lines *BOCB* is a sector.

PRACTICE QUESTIONS

(1) (a) How many right angles in an angle of 186 deg.? (b) How many 45-deg. angles?
(2) Is a 45-deg. angle an obtuse or an acute angle?
(3) How many minutes in 2.067 right angles?

Coppus Turbo Blower

The turbine of the Coppus boiler turbo-blower, Fig. 1, is of the impulse type. Upon the periphery of the wheel are over 200 closely spaced, smooth-drawn steel buckets. The bucket wheel is revolved within the turbine casing by the live-steam jets. The steam chamber is of minimum dimensions, to reduce radiation losses, being located in a current of cold air. The steam passes through three nozzles, one of which is connected directly to the steam-supply pipe while steam to the other two may be shut off for light loads by hand-operated valves. With this method of control, steam is used at full pressure. The nozzles direct the steam against the buckets at an angle of 20 deg. to the plane of rotation. A sectional view of the turbine is shown in Fig. 2.

Exhaust steam leaves at the bottom and passes through an elbow formed in the lower side of the casing and discharges in an upward direction, and thoroughly mingles with the current of air, raising its temperature before entering the ashpit. If desired, the exhaust steam can be piped to a heating or drying system.

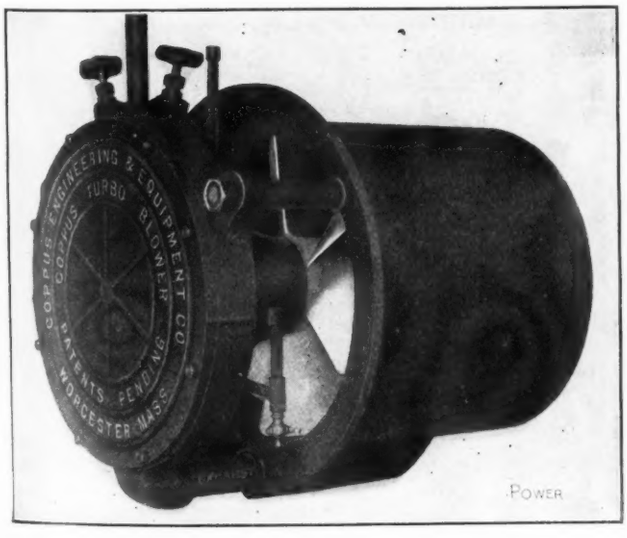


FIG. 1. COPPUS TURBO-BLOWER

The turbine and fan shaft is supported by ball bearings at both ends, protected against dirt and dust by oil-tight covers. The aluminum fan wheel is of the propeller type. A balanced valve in the turbo-steam line regulates the draft. The lever of the valve is connected to the damper regulator so that when the steam pressure drops, the damper is opened as is also the valve, both operating together. The blower then increases its revolutions and runs at the necessary speed until the steam gage registerers the predetermined pressure, when the damper closes and the blower slows down automatically.

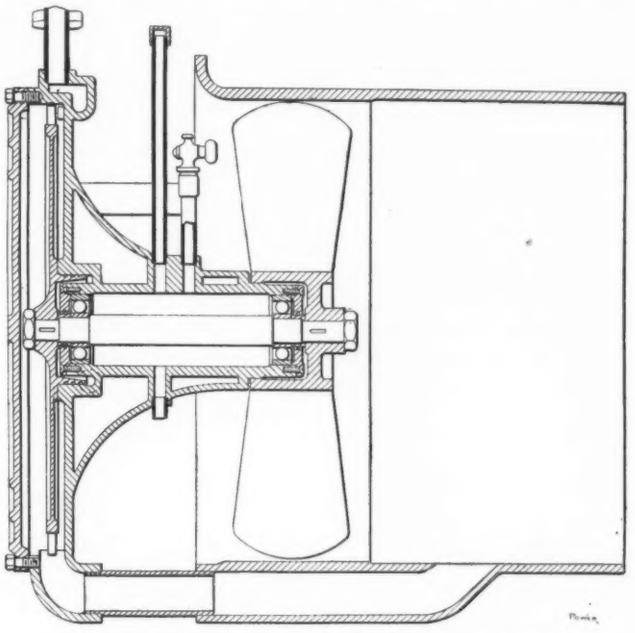


FIG. 2. SECTION THROUGH TURBO-BLOWER

This blower unit is made by the Coppus Engineering & Equipment Co., 66 School St., Worcester, Mass.

Records for the Isolated Plant

In a comparison between any isolated plant and a central station, it is very important to know exactly the cost of producing power, particularly in the case of the former, so that the rate may be compared to that offered by the central station. To obtain some valuable data along this line the Engineers' Blue Room Club, of Boston, is distributing plant data sheets to be filled out by engineers in and around Boston and in other cities throughout New England.

A summary of the data on a large number of these records should be of great assistance in determining the status of any particular plant, and in deciding on economical results generally. The data sheet is made up under headings of General Data, Cost of Power, Valuation of Equipment, Labor and Hours of Operation, Distribution of Power, Distribution of Expenditures, Detail of Operation and Equipment, Engines and Turbines, Elevators, Refrigerating Plant, Heating System, Ventilating System and Hot-water House System. Under each subhead a number of items are to be filled out, so that complete information on the type and size of equipment and cost of operation will appear in the record.

The effect of vanadium in plain carbon-steel castings is to increase the elastic limit about 30 per cent., giving a much higher proportion of available strength for the same ultimate strength.

OVER THE SPILLWAY

JUST JESTS, JABS, JOSHES AND JUMBLES

Jacob Shurt, chief engineer over to the Magnolia lighting station, according to the social column of the "Magnolia Mirror," intends spending Saturday night with his parents in Plainfield. Good luck, Jake—and good night, Shurt!

❖

Our old boyhood chum, Castor Oil, is again to the fore. "Gas Power" says it is not generally known that castor oil is one of the best of lubricants for gas-engine cylinders. Good old "Cas." While we could never really learn to love him, in our sober moments we always respected him for his good work.

❖

A Brooklyn mechanical engineer hopes to make all the heating engineers look like a discarded ice-floe. He wants Congress to help build a huge jetty over the Grand Banks, thus choking off the Labrador Current, which is now cooling the Gulf Stream. Then we'll have no more fogs and late springs, you can live in Siberia if you want to (some people have to), and Greenland's icy mountains will be likened to India's coral strands. Twenty million is the price, and it's cheap if it works.

❖

Some of our contemporaries certainly do distort the meaning of their headlines. "Electrical World" says: "Mr. Arthur Williams on the Electric Vehicle." Sounds too much like a new type of water wagon, and we know better of Mr. Williams.

❖

It's a fine summer weather this winter, Mawrus. So fine it has encouraged the Weather Bureau to say it can dope out the weather a year in advance if given sufficient appropriation. On the other hand, medical science says that if we could know the future we would go dippy. Good chance for some team-work here.

❖

While our admiration for the efficiency disciples is unbounded, we must take exception to Dr. Blackford's statement that blondes and brunettes figure in the work. We see the danger signal on our domiciliary semaphore showing red right now. The doctor says some things about blondes and brunettes that no father of a family could make his wife believe were in accordance with any set of steam tables we know of.

❖

"The locomotive raced up the track, overtook the workman, and, wonderful to relate, hurled him unhurt into the woods alongside"—Daily press. It would have been even more "wonderful" if the locomotive had left the track and chased him through the woods.

❖

Doctor Tolman, of the Museum of Safety, says that too many pants-pressers and yaps are, through political pull, made safety inspectors of shops and plants. "Give us inspectors who can inspect. Also, what's the use of asking the prospective inspector of flywheels to give the distance between New York and San Francisco?" he asks. That's it, what's the use?

❖

According to a learned professor, "between impure water and auto-intoxication there is a relation." Further discovery reveals the fact that some of the "relations" are B. Aerogenes, B. Enteriditis and B. Anaerobicus. Cricky! we thought these chaps had gone home to Greece to help fight the Turks.

❖

Some apparently unreasonable things do happen now and again. A water tower from the top down burns up (or down, and out); a fire-engine house is leveled by the demon flames; a retired sea-captain, 40 years at sea, is drowned in his bathtub at home; a veteran of 400, more or less, Indian skirmishes keeps his boots on until he gets home, and then runs a rusty nail in his toe and ptomaine (no, not "toe" this time, printer) poison carries him off. Truly, as Goethe said, or might have said, the more we live, the longer we find we are out.

American Roller Bearing

A new make of roller bearing, designed to run without lubricants, is manufactured by the American Roller Bearing Co., Farmers' Bank Building, Pittsburgh, Penn.

This bearing consists of an outer hardened-steel casing and an inner hardened-steel sleeve. Between these are

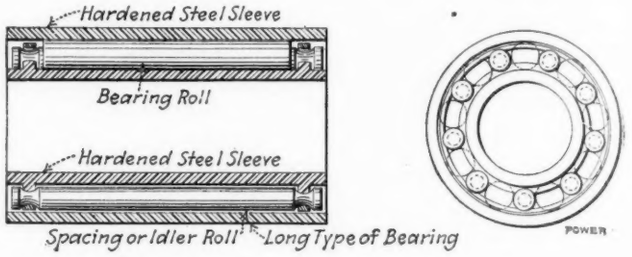


FIG. 1. SECTION THROUGH BEARING

two sets of rollers of two sizes, the larger being the bearing rollers, the smaller the spacing or idler rollers. These are shown in Fig. 1. The small rollers are ground and run on a track, and are held in place by retaining rings.

The bearing is suitable for all kinds of work. When used for line shafting, the outer sleeve fits into a shell, held in place in the hanger in the usual manner.

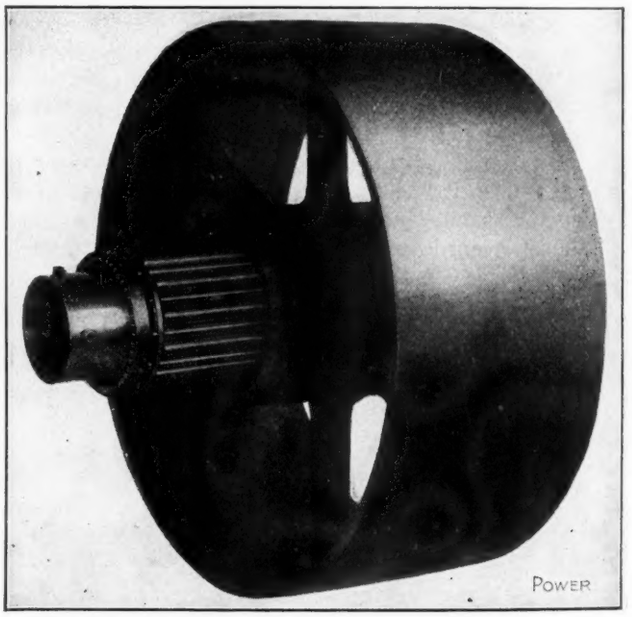


FIG. 2. ROLLER BEARING IN LOOSE PULLEY

In Fig. 2 is shown a loose pulley fitted with this kind of a bearing. It is also made with a thrust bearing, as shown.

❖

The efficiency of compressed air can be greatly increased by reheating. The gains are both direct and indirect, the chief direct gain being in the greatly increased efficiency of fuel used in the heating stoves as compared with the effect when coal is burned under boilers. It is commonly stated, and the statement is fairly correct, that when 1 lb. of coal is burned in a reheater stove the commercial effect is as great as when 3 lb. are burned under a boiler. The increase in commercial efficiency when reheating air from 60 deg. F. to 400 deg. F. may be put at 35 per cent. The indirect gains are better lubrication of the compressed-air engine; less investment required, as a smaller plant will be needed; reduction of compressor engine friction as compared with the useful work done.

Developments in Oil Burning*

By E. H. Peabody

SYNOPSIS—Characteristics and methods of handling mechanical atomizers, effect of heating oil, control of capacity, use of heavy oil, furnace design, Peabody mechanical atomizer and flat spray atomizers.

With the continued increase in oil production the use of this fuel is rapidly extending, particularly for marine purposes, and it seems worth while to point out some of the main characteristics of the mechanical atomizer and modern methods of handling it. In attempting this the writer will of necessity have to look at the subject from his own point of view, and in the light of his own experience and the experiments carried out by The Babcock & Wilcox Co.

Commodore Isherwood's conclusions of some forty years ago hold good today; namely, that the atomization of the oil, as distinguished from vaporization or gasification in the burner, "is the only method that has been attended with success." The vapor systems, while successful in metallurgical work, have no standing in boiler practice as they show no gain in efficiency but, on the contrary, result in poor capacity, the latter feature alone making them undesirable for marine use.

FIG.1 SCHÜTTE SPRAYER

FIG.2 NOZZLE OF HOWDEN BURNER

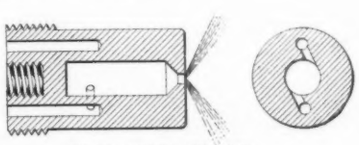


FIG.3 JONES BURNER

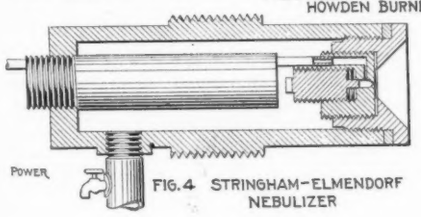
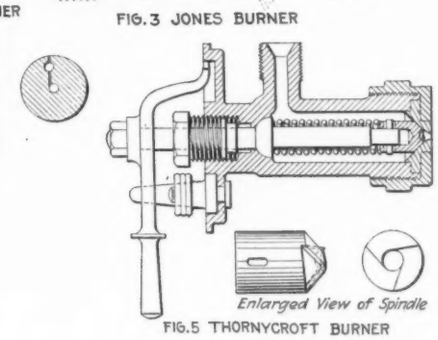


FIG.4 STRINGHAM-ELMENDORF NEBULIZER



Enlarged View of Spindle

FIG.5 THORNYCROFT BURNER

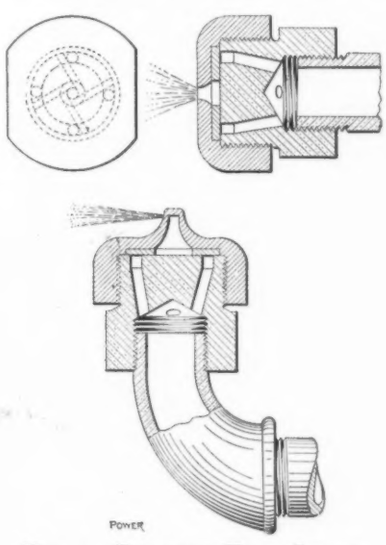


FIG. 6. PEABODY FLAT SPRAY MECHANICAL ATOMIZER

Effect of Heating Oil on Viscosity

The value of heating the oil is to reduce the viscosity of the liquid so that it can be forced through the small passages of the burner and given a rapid whirling effect sufficient to reduce it to a fine spray through the action of centrifugal force when liberated from the tip. While the viscosity is tremendously affected by changes in temperature at the lower ranges, very little difference in viscosity results with heating or cooling as the temperatures approach the flash-point.

With all ordinary oils it may be considered that heating within 50 deg. F. of the flash-point will be sufficient to render the oil suitable for use with the mechanical burner, and in the case of many of the lighter oils even this heating is unnecessary, the oil being sufficiently limpid at ordinary atmospheric temperatures.

*Abstract of paper read before the Society of Naval Architects and Marine Engineers, New York City.

Mechanical Spraying

Several methods of spraying oil by mechanical means have been suggested, such as forcing the liquid through a very fine aperture, forcing a jet of oil at high velocity against some object or against another oil jet, throwing the oil off from a rapidly revolving table or disk, or giving the liquid itself a whirling motion and reducing it to spray by centrifugal force.

In 1902 the writer tried the first idea and succeeded in making a very poor flat-flame mechanical atomizer by forcing the oil between two flat surfaces pressed closely together, and in 1907, some of the other schemes. The experiment of making two round jets of oil strike each other on the principle of the acetylene burner, resulted in a flat spray—not fine enough, however, with heavy oils to be practicable. A mechanical atomizer, or, as it was called, a "self-atomizer," consisting of eight small jets meeting at a central point, was patented in England in 1904 by Charles Ferdinand de Kierkowski Steuart. It is a good example of spraying by forcing jets of oil to strike each other, but otherwise has attained no importance in the art.

The only method of atomizing fuel oil mechanically which has attained any practical success is that wherein the oil is given a whirling motion inside the burner tip. There are two distinct means of doing this, first, by forcing the oil through a passage of helical form, like a screw thread, and second, by delivering the oil tangentially to a circular chamber from which there is a central outlet.

Fig. 1 is an illustration of the first form, the "spraying nozzle" patented in the United States in 1895 by L. Schütte. Another adaptation of the same idea is shown in a patent taken out in England in 1899 by James Howden, Fig. 2. He refers to heating the oil by means of live or exhaust steam or the waste gases, pumping it into an accumulator or air receiver for neutralizing the

pulsations of the pump, and then projecting the oil into the furnace in the form of fine jets or spray by passing it through a nozzle having helical grooves on a part of the spindle within the nozzle, so as to impart a whirling motion to the oil. Howden's burner is adjustable in that the taper spindle moves "up and down" in the taper passage leading to the nozzle orifice. This movement of the spindle increases or decreases the area of the outlet passage, thus controlling the amount of oil delivered by the burner, but the helical passage is not affected.

The idea of delivering the oil tangentially to a chamber inside the nozzle is shown in a burner patented in England by Albert Edward Jones in 1907, Fig. 3. This invention contemplates the use of a gas or vapor in combination with a combustible liquid and is not strictly a mechanical atomizer, but the device is almost a diagrammatic illustration of the tangential principle. It may be considered that oil is forced into both tangential passages, or that only one is used, this depending only on the whirling motion of the oil to cause the spraying.

A so called "nebulizer of the heavier hydrocarbons," patented in this country in 1908 by Stringham and Elmendorf, is a good illustration of the further development of the tangential principle and is shown in Fig. 4. This apparatus was water-cooled, a precaution not found necessary in connection with boiler furnaces.

Modification or combinations of the tangential and helical forms of burners are frequently encountered in the art, and an illustration of one of these is shown in Fig. 5. This is an ingenious burner patented in England by Sir John Thornycroft in 1906, in which it may be noticed that the oil passages within the tip are made variable in area of cross-section by an adjustment of the spindle, thus varying the quantity of oil delivered without alteration of either oil pressure or size of outlet passage. This renders the burner adjustable like the Howden, though by a different process, in that in the Howden burner the helical passages remain unaltered and only the outlet orifice is changed.

Control of Capacity

This matter of adjustability of an oil burner, that is, the ability to change the quantity of oil delivered in a given time without changing the oil pressure or the velocity of the liquid through the tip, while attractive and perhaps well sustained in theory, has no particular value in practice. It is a fact that the simpler forms of burners which do not possess this feature are quite as, if not more, successful in regular operation on shipboard. The manipulation of the oil pressure acting on all burners at once presents in itself a simple means for the control of output through a wide range; a good burner will atomize moderately heavy oil with an oil pressure as low as 30 lb., and from that up to 200 or above. If this range is insufficient to meet the variable steam requirements, then it is easier and better to shut down a portion of the burners entirely than to attempt to adjust each individual burner separately, particularly as it is important to regulate the quantity of air for combustion admitted to the furnace at the same time the quantity of oil is varied. This air supply can easily be controlled for all burners by regulating the draft pressure, and the air can be closed off entirely when a burner is shut down. This puts the question of air supply more into the hands of the designer, requiring the operator to determine only the proper conditions of draft pressure for the plant as a whole, at the required capacity.

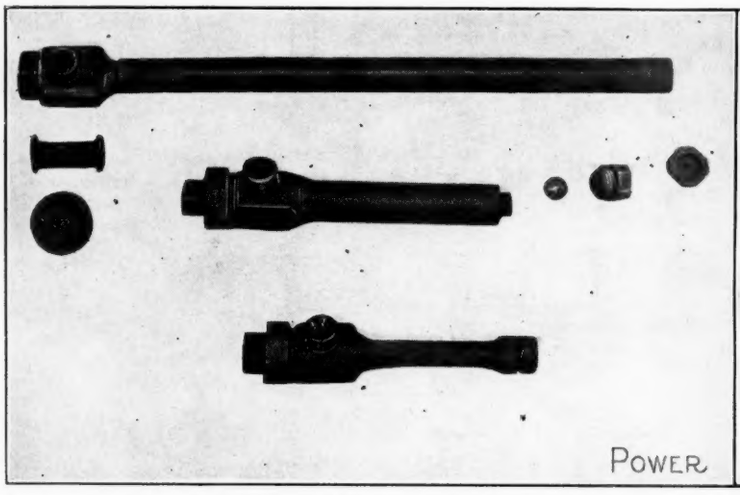


Fig. 7. Peabody Mechanical Atomizer

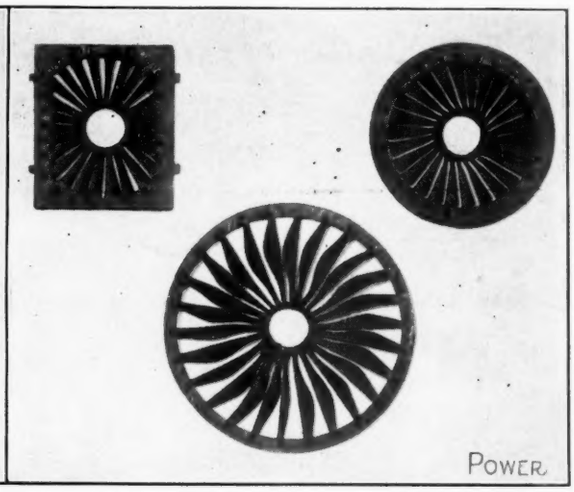


Fig. 8. Impeller Plates

Effect on Heating

Another means of varying the quantity of oil delivered by all burners in addition to alteration of oil pressure is available in alteration of oil temperature. Generally speaking, under working conditions any increase in temperature of the oil results in decreased capacity of the burners, the pressure remaining the same. The reverse is the case at low temperatures, the critical point depending on the relationship between viscosity and specific volume of the oil in question.

Requirements of Mechanical Burners

It will be obvious, if oil is to be atomized by centrifugal force, that the best spray will be obtained by giving the oil the maximum whirling motion and reducing to a minimum the friction in the burner so that the whirling motion once obtained shall not be diminished before the oil is liberated. It would appear that the tests should be:

1. How heavy an oil will a burner thoroughly atomize?
2. What pressure and temperature are necessary?

3. What degree of simplicity has been attained in the design?

Use of Heavy Oil

Any apparatus which will not handle heavy oil will have a very limited usefulness. Already the market is beginning to be supplied with very heavy oils from Mexico, there is considerable crude oil in California below 15 deg. gravity, and the tendency will be more and more to use the heavier residuums. In a few years we will be using oils of 12 to 15 deg. Baumé as commonly as we are consuming oil of 27 and 30 deg. gravity today.

The Babcock & Wilcox Co. recently received from The Texas Co., for experimental purposes, some Mexican crude oil having the following characteristics:

Specific gravity at 60 deg. F.	0.981
Degrees Baume at 60 deg. F.	12.6
Moisture and silt	3.5
Flash-point	310
Burning point	347
B.t.u per pound (oil as received)	17,551

In appearance this oil was black and at temperatures of about 80 deg. very sticky and viscous. On heating to 212 deg. it turned to foam owing to the presence of so much water, and this failed to separate out, a sample of the oil being thinned down with ether to determine the percentage. Ordinary settling tanks would have been practically useless as the oil was so near the specific gravity of water. This oil was, however, successfully sprayed and burned under natural draft, on being heated to 270 deg. at a pressure of 165 lb. A slight amount of smoke was formed which disappeared on a slight increase in the furnace draft above 0.12 in. of water. The most noteworthy feature of the experiment was that the capacity fell off about 40 per cent. from that obtained with the same apparatus with oil of 18 gravity.

The accompanying table of densities is given for convenient reference.

DENSITY OF OIL

Degrees Baume	Specific Gravity	Pounds per Gallon	Degrees Baume	Specific Gravity	Pounds per Gallon
12	0.986	8.22	24	0.913	7.61
14	0.973	8.11	26	0.901	7.51
16	0.960	8.00	28	0.890	7.42
18	0.948	7.90	30	0.880	7.33
20	0.936	7.80	32	0.869	7.24
22	0.924	7.70			

Peabody Mechanical Atomizer

In the light of experiments begun in 1907 we have come to believe that the best rotative effect on the oil is produced by the tangential delivery method, and it seems plain that the best way to reduce friction is to reduce the amount of surface to which the oil is exposed in its travels through the burner after it begins to whirl and until its exit from the tip. Great importance is attached to simplicity in everything connected with oil burning. The oil burner itself should be of simple construction, easily taken apart, and so designed that when taken apart all the small passages and wearing surfaces will be exposed for inspection, cleaning and repair.

In the writer's burner, Fig. 7, oil is delivered under pressure to an annular channel cut into the face of a nozzle upon which is screwed a tip having a small central chamber communicating with a discharge orifice. Between the nozzle and the tip a thin washer or disk is inserted and held firmly in place. This has a hole in the center corresponding with the diameter of the central chamber of the tip, and small slots or ducts, extending tangentially from the edges of the central opening outward toward the periphery of the washer, long enough to overlap the annular channel of the nozzle and put it in communication with the central chamber. The effect is that when the burner is assembled with the washer in place, oil is delivered through the ducts tangentially to the central chamber, where it rapidly revolves and almost immediately is discharged through the orifice in the tip.

Character of Mechanical Spray and Effect on Combustion

No mechanical atomizer produces a revolving spray, but the particles of oil fly off in straight lines under the influence of centrifugal force, thus forming a hollow, conical spray. The fineness of this spray, i. e., the minuteness of the particles forming it, has a most important bearing on the results obtained in the furnace. It is possible with some forms of steam atomizers to atomize oil so finely that no flame at all will be produced, the incandescent combustion chamber being filled with a clear, invisible gas and every brick being discernible.

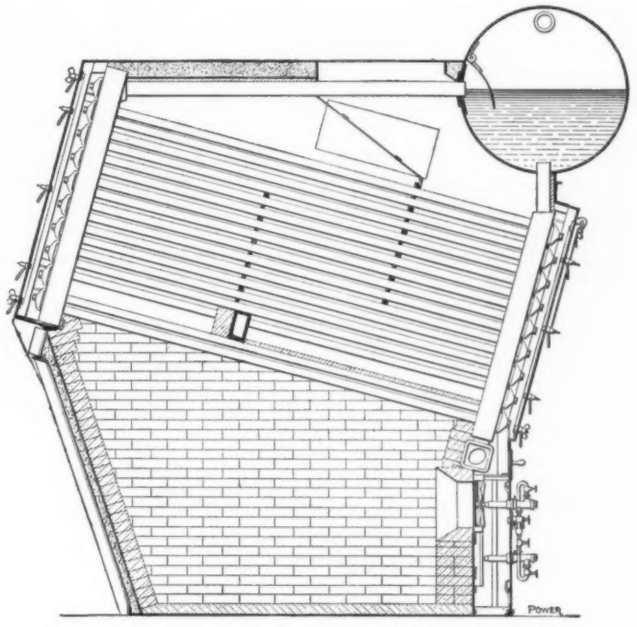


Fig. 9. Furnace of Babcock & Wilcox Boiler

It is doubtful if this condition of flameless combustion can be produced with mechanical atomizers and heavy oil, nor is it desirable under any circumstances, for the simple reason that it costs too much.

With production of flame, however, furnace design assumes an added importance, for the flame must be distributed evenly and without localizing on the heating surfaces of the boiler, and the gases must be given time and space in which to expand and burn as nearly as possible to completion before being cooled and the flame extinguished by contact with the tubes of the boiler. These points become exceedingly vital when the boiler is forced to the requirements now demanded in naval service.

Furnace Design

Having an atomizer that will produce a fine spray with heavy oil and which is simple, reliable and easily handled, the problem becomes one, not of oil burner, but of furnace

design and air distribution. Our work has been carried on, until recently, entirely with the Babcock & Wilcox marine boiler, a design having a furnace suited for any volatile fuel and particularly for oil. A longitudinal section through this boiler fitted with mechanical atomizers is shown in Fig. 9. The characteristics of this furnace are: Large volume in proportion to the heating surface of the boiler; upward slope of the roof toward the rear, resulting in increase in height and volume in the direction of the entering oil spray and thus providing room for the expansion and diffusion of the gases; small amount of boiler heating surface exposed, and, on the contrary, large exposed surface of incandescent refractory material, thus tending to maintain high furnace temperature and promote complete and rapid combustion of the oil; tubes almost parallel with the path of the oil spray injected into the furnace from the front, thus promoting proper distribution of the gases along the tubes and preventing local overheating; outlet from the furnace at the point most remote from the location of the atomizers, insuring long travel of the gases; and, finally, means for bringing the heated products of combustion into the closest possible contact with the entire amount of heating surface of the boiler, discharging the waste gases into the uptake at temperatures but little above that of the steam generated.

[Reference was made in the paper to the tests made on the steam yacht "Idalia" and the guarantee tests for the "Wyoming," in which coal, oil and a combination of the two were used as fuel. The results of the tests with oil fuel were published in POWER of Aug. 1, 1911. In both cases the flat-blade impeller plate was found to be most suitable, and a considerable number of small burners and impeller plates were preferable to a few of larger size. In the "Wyoming" an evaporation from and at 212 deg. F. of 13.16 lb. of water per hour was obtained and a combustion of 13.69 lb. of oil per cu.ft. of furnace volume, which is equivalent to about 75.34 lb. of coal per square foot of grate area in the same boiler.—EDITOR.]

FLAT SPRAY ATOMIZERS

Mention has been made of a flat-flame atomizer formed of two flat surfaces pressed together, and another consisting of two round oil jets striking together. Neither of these schemes seemed to promise very much in the way of material for development. Another form which does seem to possess some merit is illustrated in Fig. 6. This consists of a means for giving the oil a rapid whirling motion as in the case of the round-flame burner and then releasing the liquid through a slot in the side of the tip in a plane at right angles with the axis of revolution instead of through an orifice concentric with the axis. It is apparent that centrifugal force will here come into action as an atomizing agent but that the spray will be flat instead of conical.

(To be continued)

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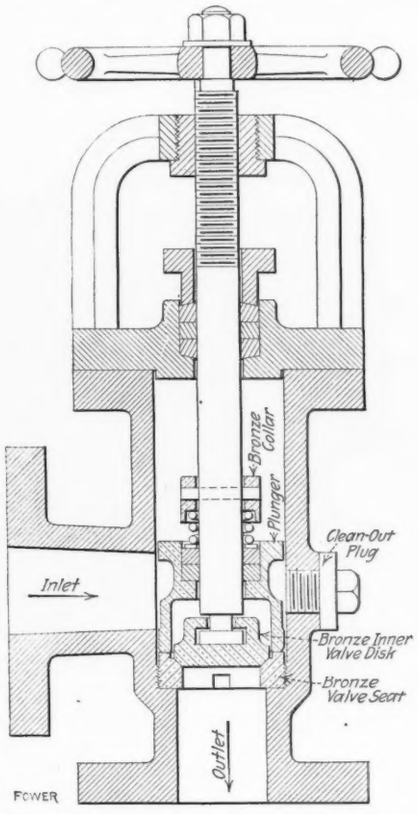
On an average a man dissipates about 2.5 kw.-hr. per day. This is spent partly in muscular action, partly in the production of heat in the maintenance of the body temperature against radiation. There is thus a continual power consumption of about 100 watts, or one-seventh of a horsepower. About one half of this is spent in maintaining the body temperature. The human body has about the same heating effect upon the surroundings as a 16-cp. carbon filament lamp.—"Scientific American."

Vance Compound Blowoff Valve

A new blowoff valve is being placed on the market by the George M. Newhall Engineering Co., Philadelphia, Penn. The feature of its construction is a double-disk arrangement to protect the valve seats from the action of sludge and scale coming from the boiler.

Referring to the illustration, the outside plunger protects the disk valve from coming in contact with any destructive elements, no matter how far the valve is open or closed. Each valve disk seats individually, the plunger first and then the disk.

When the plunger passes the inlet in closing, the flow is practically cut off, and only a thin sheet of water passes



VANCE COMPOUND BLOWOFF VALVE

over both seats to clear them of sediment, until the plunger seats; when tight, the disk valve seats with no water passing through. On opening, the disk valve leaves its seat first, because the spring holds the plunger in place until after the disk valve moves up into the protective covering of the plunger out of the way.

The disk valve works on a slip joint, and is easily removed. Precaution has also been taken to protect the valve seats by placing them below the direct line of the sludge as it comes from the boiler. These seats are removable for regrinding or renewing. All working parts are bronze. The valve stem screws through a bushing in the yoke of the valve. The stuffing-boxes are deep to insure room for sufficient packing to keep the valve stem tight. The valve is made extra heavy throughout.

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For utilization of the water power of Finland, and for conducting part of the energy obtained at St. Petersburg, a new Belgian share company will be established in Brussels with a capital of $6,000,000. A considerable number of international banks, it is said, are taking part in the subscription to the foundation capital.

Goulds Centrifugal Fire Pump and Power Head

A new design of centrifugal fire pump, made by the Goulds Manufacturing Co., Seneca Falls, N. Y., is furnished complete with pump, direct- or alternating-current motor, or steam turbine, bedplate and all fittings required by fire-insurance companies; it has also been approved by the Association of Mutual Factory Fire Insurance Companies.

Four sizes are made, with capacities of 500, 750, 1000 and 1500 gal. per min., for two, three, four and six effective fire streams respectively. All working parts are of bronze to prevent corrosive action from the water.

The 500-gal. equipment for two effective streams, with 250-ft. leads of smooth hose and 1⅛-in. hose nozzles, produces a nozzle pressure of 50 lb. per sq.in. and an effective stream in a modern wind reaching a vertical height of 70 ft. and a horizontal distance of 63 ft. The 50-hp. motor runs at 1700 r.p.m. The overall dimensions of the complete outfit are: Length, 9 ft. 7 in.; width, 6 ft. 3 in.; height, 4 ft. 9 in.

A new power head has also been developed for operating cylinders in deep wells in connection with pneumatic-pressure water-supply systems. In addition to pumping the water from the well, it also supplies the air pressure for the tank. Compressed air is obtained by a special air cylinder mounted on the frame near the top. The plunger of this air compressor is operated by a rod connected to the crank rod of the working head by an extension of the pin connecting the crank rod to the well rod. A pipe from the air cylinder connects it with the discharge of the working head. This air pipe contains a check valve and the necessary couplings. A cock is provided so that the air will not go to the tank when it is open and the outfit is relieved of air pressure when it is not needed.

By taking out the bolts which secure the well cover to the frame and disconnecting the well rod, the plunger can be withdrawn from the well without disturbing pipe connections or moving the working head. The gear ratio is 5 to 1 and the tight and loose pulleys supplied are 16x3 in.

Marine Engineers' Convention at Charleston, S. C.

The thirty-eighth annual convention of the Marine Engineers' Beneficial Association was held at Charleston, S. C., during the week commencing Monday, Jan. 20, with headquarters at the New Charleston Hotel.

There were 48 delegates present from all parts of the United States, and 16 supply houses were represented. The several sessions of the delegates were held in the banquet hall of the hotel, where considerable important business was transacted with dispatch. The delegates and visitors were warmly welcomed to Charleston by Mayor John P. Grace and other prominent city officials.

There was an enjoyable series of entertainments, including automobile rides for the ladies, an "oyster roast" at Schuetzen Park, an entertainment and ball at the German Artillery Hall, and a steamboat ride to Fort Sumter. The special feature of entertainment, which proved a fitting conclusion to this successful convention, was the smoker on Thursday night at the German Artillery Hall, to which the business men, manufacturers, city officials and other interested citizens of Charleston were invited. A splendid vaudeville performance was given and refreshments of all kinds were served.

The election of national officers by the Marine Engineers' Beneficial Association for the ensuing year resulted as follows: William F. Yates, president; David W. Miller, first vice-president; George H. Bowen, second vice-president; Charles N. Vosburgh, third vice-president; George A. Grubb, secretary; Albert J. Jones, treasurer; William S. Brown, Frank J. Houghton and Edwin P. Groff as members of the advisory board.

ENGINEERS AND GUESTS AT THE CHARLESTON CONVENTION

At the closing meeting of the Supplymen's Association the following officers were elected: Charles F. Heitzman, president; R. R. Row, vice-president; Charles A. Wilhoft, secretary-treasurer.

The next annual meeting will be held at Washington, D. C., in January, 1914.

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Tests of double check-valve systems are made every month by the water department of Hartford, Conn. Fourteen manufacturing companies in the city now maintain these systems on fire service pipes for their automatic sprinklers. The secondary water supplies are obtained from the Park River or other polluted sources so that they must be segregated from the city's mains carrying water for domestic use. It is important, however, that the check valves be in proper working order at all times to meet emergencies in the form of larg fires. The valves, as described in the annual report of Caleb M. Saville, chief engineer, are fitted with leakage testing devices and automatic alarms which ring in the offices of the factory superintendents. The monthly tests, according to the report, have shown that the check valves are operating satisfactorily.

N. A. S. E. License Committee Report

The following is an abstract of a recent report made to John F. McGrath, national president of the National Association of Stationary Engineers, by the National License Committee, C. H. Wirmel, John J. Coughlin and James Rostron:

The National License Committee held a two-days' session beginning Saturday, Dec. 14, at Pittsburgh, Penn. Proposed bills submitted by the states of Indiana and Oregon, with a few minor modifications, were approved. The Indiana bill, submitted by Chairman Heeger of the state committee, and endorsed by all of the state engineers' organizations, provided for a board of examiners of four members, the chief examiner acting as president, and the examining, licensing and classification of engineers and firemen. The examination fee is $3, and the fee for renewals, to be made annually, is $3, thereby making the department self-sustaining. The examining board is authorized to reduce the fees when they exceed the expense of operating the department.

The Oregon bill, which combines an engineer's license law and a boiler-inspection law, is a model of its kind and framed to meet present-day requirements. It provides for a board of rules of four members, a chief inspector, 10 deputy inspectors and a secretary; all inspectors to be selected by the merit system. The fee for internal-boiler inspection is $5, and that for inspection while in operation, $2. It further provides for the examination, classification and licensing of engineers and firemen. The application fee is $1, and the license is issued for an indeterminate period to be revoked for cause and renewed upon affidavit, when destroyed or lost. Penalties of fines and imprisonment are provided for employers and engineers violating the law. The annual renewal and license fee is eliminated. This, together with the requirement that the engineer keep a daily record of the condition and repair of all boilers carrying over 251-lb. pressure, are two very important features that should commend the bill to the favorable consideration of both the steam user and the engineer.

Mr. Rostron reported that Delaware, having made four attempts to secure a state law, may compromise on an enabling act, thus giving cities the right to enact local ordinances; that Mr. Case, of New Jersey, has secured over 10,000 signatures to his petition for a license law, with good prospects of passage at the coming session of the legislature; that Mr. Lee, of the New York license committee, will call a meeting later to determine the future policy of the committee; that the Maryland committee reports progress on its proposed bill; that South Carolina, which some years ago made a futile effort to secure a law, again desires to take up the matter and will negotiate with the National License Committee to that end; that the prospect of presenting a bill to the Pennsylvania legislature during the coming session was likely.

Mr. Coughlin reported that as the Kentucky legislature would not meet until 1914, license work in that state would be deferred until that time; that prospects in Indiana, with all engineer's organizations united on a bill, looked favorable for its passage at the coming session of the legislature.

Mr. Wirmel reported favorably on the Michigan, Illinois and Wisconsin state bills and on the Aberdeen (S. D.) ordinance; that the work in Ohio to broaden the scope of the boiler-inspection law and to eliminate the engineers' license renewal fee would be submitted to the legislature. He was authorized to confer with National President McGrath as to lending financial assistance to the several state committees.

In response to numerous demands, the committee decided to secure the license and boiler-inspection laws of the national government, the several states and cities, and refer them to the coming national convention for compilation and publication. Mr. Rostron was assigned to look after the Eastern states and Messrs. Wirmel and Coughlin to the Central and Western states.

License Legislation in New Jersey

The combined associations of the New Jersey N. A. S. E. and the American Order of Steam Engineers have prepared a proposed "enabling" law to be presented to the legislative bodies of that state.

If passed it will empower the board of aldermen or other governing bodies of any municipality to provide by ordinance for the examination and certification of persons having charge of or operating stationary and portable steam engines and boilers. It requires that the charges made for examination and certification shall not exceed $2.

Electricians Make Brave Rescue

Charles Sanges and Frank Bettles, electricians of the Mobile Electric Co., Mobile, Ala., displayed rare bravery recently in rescuing two firemen who had been buried beneath the débris in a fire which destroyed the Mobile theater.

Manager Jackson, of the Mobile Electric Co., said: "These men at the risk of their lives, were lowered by ropes attached to their belts into the smoldering tons of brick to rescue the firemen. The red-hot bricks were removed and the two firemen released from their awful predicament. Although burned and blistered, the linemen went back to their work after receiving medical attention and resumed their daily duties."

N. A. S. E. Lantern Slide Catalog Read

The catalog of lantern slides on steam turbines issued by the National Association of Stationary Engineers is being sent out to the various associations. At the Kansas City convention the association directed that pictures be prepared to illustrate technical subjects and a scheme started for loaning these slides to subordinate associations.

Briefly, the plan is this: Custodians have been appointed in 12 cities who will take charge of the slides and issue them to associations on application. Fifteen duplicate sets are to be prepared, one for each custodian, with two sets in some of the larger districts. The slides on steam turbines have already been sent out; the second set, on steam boilers and stokers, will be sent shortly, followed by sets of pictures to illustrate gas power plants. Other subjects are in preparation.

Apparently the scheme is a good one, as within six days from the date the application blanks were issued, one of the custodians received 28 applications for the slides. Within the next month there will be three subjects in circulation and 15 duplicate copies. The N. A. S. E. will supply the associations as promptly as possible.

OBITUARY

JOHN B. PERKINS

John B. Perkins, of the John B. Perkins Co., Boston, died on Jan. 19 at his late home in Auburndale, Mass., after a lingering illness, at the age of 43.

Mr. Perkins' career began as an operating engineer. He was chief engineer of the Watertown pumping station before entering the employ of the Garlock Packing Co. some eleven years ago. Later he went with the Crosby Steam Gauge & Valve Co., and then became a manufacturers' agent, his business developing into the formation of the John B. Perkins Co. A man of strong personality and determination, many of Mr. Perkins' friends attribute the initial cause of his death to overwork.

PERSONALS

R. W. Williamson, for the past three years city electrician of Shreveport, La., and local representative of the Louisiana Fire Prevention Bureau, has tendered his resignation to accept a position with the Alabama Power Co.

Edwin M. McClintock, superintendent of stations of the Union Gas & Electric Co., Cincinnati, and William F. Vance, chief electrician of stations, have resigned to go with the Superior Carbon Specialty Co., of that city. Both were connected with the company over nineteen years.

Col. George W. Goethals, chairman and chief engineer of the Isthmian Canal Commission, was the guest of honor at a dinner given by the Lehigh University Club of New York, at the Hotel Astor, Jan. 27. Besides members of the club, a number of prominent engineers were invited guests.

Frank F. Fowle has severed his connection with the McGraw Publishing Co. as one of the editors of "Electrical World," and will resume his electrical engineering practice with offices at 66 Maiden Lane, New York City. As a consulting electrical engineer, Mr. Fowle is widely known. He is a member of the American Institute of Electrical Engineers, the Illuminating Engineering Society, the National Electric Light Association, the Railway Signal Association and the Technology Club of New York.